Phytotoxicology Soil Investigation:
INCO – Port Colborne (1998)

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1.0 Executive Summary

Results of the 1998 Phytotoxicology investigation confirmed that soil to a depth of at least 15 cm in the Port Colborne area is severely contaminated with nickel, and to a lesser extent with copper and cobalt. Soil nickel background concentrations (43 μg/g) are exceeded beyond 13 km northeast of INCO over an area greater than 159 km^2, and more than 4 km in the same direction for copper (85 μg/g, 8.9 km^2) and cobalt (21 μg/g, 6.1 km^2). Soil nickel concentrations exceed the effects-based MOE soil remediation criterion (200 μg/g) up to 8 km northeast of the refinery over a 19 km^2 area. The soil remediation criterion for copper (300 μg/g) is exceeded over a 0.3 km^2 area, and 1.6 km^2 of area is contaminated with cobalt above the criterion (50 μg/g). Nickel is the most significant of these three contaminants. Soil nickel concentrations exceeding the remediation criterion are potentially phytotoxic; for example, a reduction crop yield and/or foliar injury on sensitive species of vegetation. A health study conducted by the MOE (*Technical Report: Assessment of Potential Health Risks of Reported Soil Levels of Nickel, Copper, and Cobalt in Port Colborne and Vicinity, May 1997*) and based on a multi-media assessment of potential risks concluded that no adverse health effects are anticipated to result from exposure to soil metal contamination in the Port Colborne area.

The soil metal contamination in the Port Colborne area is unquestionably source-oriented, resulting from 66 years of atmospheric deposition from the INCO refinery. These heavy metals are very persistent in soil. Since INCO emissions ceased several years ago, further increases in soil metal concentrations will not occur. Subsequent reductions in soil metal concentrations as a result of natural processes will be extremely gradual. With the cessation of emissions, common landscaping practices at residential properties in the Port Colborne area are affecting local surface soil metal concentrations by creating a patchwork of higher and lower metal levels, which is superimposed on an obvious concentration gradient relative to INCO. Therefore, future periodic surface soil sampling that indicates a reduction in soil metal concentrations would likely be due to disturbances to the sod/surface soil layer rather than actual reductions in the soil contaminant burden. In the absence of INCO emissions and through continued disturbance of surface soils a mosaic of soil metal concentrations will likely become increasingly more prevalent in Port Colborne. However, potentially phytotoxic concentrations of metal contaminated soil would remain just below the layer of cleaner soil and sod on these superficially remediated properties.

Agricultural tilling tended to reduce the metal concentrations in the surface soil layers but increase the concentrations at depth, essentially spreading the contamination throughout the plow layer. The difference between tilled and untilled sites was greatest farthest from INCO, with the metal concentrations at surface being higher in the untilled sites. However, at tilled sites closer to INCO soil metal contamination was not consistently different from untilled sites but the contamination at the tilled sites extended deeper into the soil profile, exceeding the remediation criterion at depths greater than 30 cm. Therefore tilling may exacerbate remediation efforts as the contamination has been distributed deeper into the soil.

Despite a more extensive sample strategy the complete impact area was not determined, as soil nickel concentrations collected from the farthest downwind sites (>13 km) were still about twice background values. Sampling was adequate in the city core to accurately estimate the surface soil metal contamination gradient. Localized site disturbance and data variability may have slightly skewed the computer-generated contaminant contours resulting in an overestimation of the area to the northwest of Port Colborne with soil nickel concentrations in the 100-200 μg/g range and an underestimation of the 200-500 μg/g nickel contamination zone to the northeast of INCO.

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6.0 Introduction and Historical Perspective

In 1916, the Government of Ontario established the Royal Ontario Nickel Commission to investigate the potential problem of nickel (Ni) falling into the hands of the enemy during World War I. To ensure that the allies maintained full control of a critical metal commodity, it was necessary to ensure that all phases of Ni production remained on-shore. In response to the Commission's findings, International Nickel constructed a Ni refinery at Port Colborne. This base metal refinery operated from 1918 to 1984 [Ref.1]. At present, International Nickel Company Limited (INCO) is in the process of decommissioning the site of their historical Ni refinery in Port Colborne. Currently INCO operates only a precious metal and electro-cobalt recovery facility in Port Colborne, neither of which produce significant atmospheric emissions.

The Phytotoxicology and Soil Standards Section of the Ontario Ministry of Environment (MOE) has conducted several extensive soil and vegetation investigations in the vicinity of INCO in Port Colborne, the earliest being 1972 [Refs.2,3,4,5]. A complete list of MOE Phytotoxicology INCO Port Colborne investigation reports is provided in Appendix E. The Phytotoxicology investigations identified significantly elevated concentrations of Ni, copper (Cu), and cobalt (Co) in soil and vegetation as a result of emissions from the refinery. Concentrations of these elements in soil and vegetation in Port Colborne in the vicinity of INCO consistently exceeded the former Phytotoxicology Upper Limit of Normal (ULN) guidelines [Ref.6].

A Phytotoxicology soil investigation conducted in 1976 identified surface soil (0-5 cm) Ni concentrations as high as 23,800 μg/g (micrograms per gram, also referred to as parts per million, or ppm) [Ref.3]. Soil Ni concentrations exceeded the former ULN guideline of 60 μg/g more than 8 km downwind (east-northeast) of INCO. Copper and Co concentrations were also substantially elevated in surface soil. A maximum Cu concentration of 1,790 μg/g and a maximum Co concentration of 455 μg/g occurred concurrently with the highest soil Ni concentration. There was a strong statistical co-relation between the three elements, and the concentration gradients clearly implicated INCO as the source of contamination. The number and location of sample sites in 1976 was insufficient to define the extent of soil contamination in both the northeast and northwest directions (background concentrations were not achieved in either direction). The concentration gradient was almost exponential within 1 km of the refinery. However, it was difficult to accurately predict local pollutant trends because there were insufficient numbers of sample sites in this 1976 investigation.

In 1986, a Phytotoxicology vegetation investigation was conducted around INCO in Port Colborne [Ref. 4]. Generally, foliar chemistry reflects the air chemistry that the plants are exposed to during the growing season. The highest foliar Ni, Cu, and Co concentrations were co-located with the highest soil metal concentrations. Foliar ULN guidelines were exceeded for Ni and Co, but not for Cu. Like the soil contamination, there was a clear and consistent concentration gradient that unquestionably implicated INCO as the source.

Foliar injury characteristic of Ni toxicity was observed on street trees in Port Colborne throughout the 1970s and 1980s. The foliar injury was consistently more severe and the foliar metal concentrations were consistently higher in foliage collected from the side of sample trees facing INCO, compared to foliage collected from the opposite sides of the crowns of the same trees. This technique of sampling opposite sides of the same tree crown helps to distinguish between effects caused by current ambient emissions and the contribution of contaminant uptake from the soil. It was clear that ambient emissions were responsible for most of the injury observed on street tree foliage during the earlier investigations. However, Ni injury is still evident on some trees in Port Colborne (observed in 1998), although less severe, in areas where soil Ni contamination is significant, confirming that uptake of Ni from contaminated soil is occurring.

A soil and vegetation investigation was conducted again by the MOE Phytotoxicology Section in 1991, seven years after commercial operations had ceased [Ref.5]. One objective of the 1991 investigation was to more accurately define the extent of surface soil contamination and determine if soil contaminant levels had changed in the 15 years since the 1976 survey was conducted. A second objective was to determine if current ambient (fugitive) emissions and/or soil contamination was still causing Ni toxicity to street and ornamental trees in Port Colborne.

The 1991 investigation confirmed that soil to at least 10 cm in depth was still severely contaminated with Ni, and to a lesser extent, with Cu and Co. Former ULN and/or 1989 MOE soil guidelines [Ref.7] for soil Ni were exceeded beyond 6 km in a northeast direction, and beyond 2 km northeast for both Cu and Co, respectively. The soil Ni concentrations were sufficiently elevated to limit normal agricultural land use up to at least 4 km northeast and east of INCO. The agricultural limitations would potentially include reduced yields of cereal crops (particularly oats) on mineral soil and stunted, chlorotic, metal-enriched vegetable crops on organic soil. The 1991 investigation concluded that the extent and severity of soil metal contamination was essentially unchanged from 1976.

Injury characteristic of Ni toxicity was still observed on vegetation in 1991 and during visual surveys in 1992 and 1993. Silver maple showed a significant range in relative sensitivity to Ni toxicity; however, the injury was very scattered, and occurred only in the immediate vicinity of INCO where soil nickel concentrations were known to be extremely elevated. It was concluded that the vegetation injury was related to uptake of Ni from contaminated soil rather than ambient (fugitive) emissions from the refinery.

The 1991 investigation was successful in better defining the area of surface soil contamination in the zone where the concentration gradient was steep (within about 3 to 4 km of INCO). However, the extent of contamination to the northeast and east was not identified. Results of the 1991 investigation suggested that an additional soil survey was warranted and should include a grid of sample sites out to at least 8 km in the westerly directions and up to 15 km in the northeasterly and easterly directions.

7.0 Objectives of the 1998 Investigation

Atmospheric emissions associated with over 65 years of Ni refining have resulted in most of the area within the Port Colborne city limits having soil Ni concentrations that not only exceed the Ontario background soil Ni level (43 μg/g) but also exceed the current MOE soil remediation criterion for Ni (200 μg/g) [Ref.8, *Guideline for Use at Contaminated Sites in Ontario,* hereafter the current remediation criteria will be referred to simply as the *Guideline* - see Appendix C]. The Ni *Guideline,* as well as the *Guideline* for Cu and Co, are based on phytotoxicity (plant effects). The growth of some plant species may be adversely affected by soil contamination that exceeds these *Guidelines*. Foliar injury, characteristic of Ni toxicity, was observed on silver maple trees in the immediate vicinity of INCO during a visual survey of vegetation in 1998. Since refinery emissions have ceased this injury can only be related to uptake of Ni from contaminated soil.

The City of Port Colborne is concerned that the presence of extensive soil Ni contamination above current MOE soil *Guidelines* could interfere with scheduled amendments to their Official Plan, which would allow for re-zoning of large tracks of contaminated agricultural land for residential development, and that Port Colborne may be perceived as a contaminated community, which could deter residential immigration. In response to the City's concerns, the MOE Niagara District Office required a more comprehensive understanding of the extent and severity of heavy metal soil contamination in the Port Colborne area. For this reason, the Phytotoxicology Section of the Standards Development Branch was requested to provide the following :

1. Repeat the 1991 soil investigation (i.e. revisit the 1991 sites),

2. Increase the number of sample sites to include the rural area around Port Colborne to more accurately define the spacial extent of nickel contamination,

3. Include a subset of soil profile sites to be sampled at various depths to determine the depth of contaminated soil (which may be useful in estimating the volume of contaminated soil), and,

4. Include a subset of cultivated sites and uncultivated sample sites to determine the impact of agricultural practices on soil contaminant levels.

An additional objective of this study was to utilize the investigation data in state-of-the-art computer contour mapping procedures to provide a reasonable estimate of the total areas of impact that exceed 1) the Ontario soil background-based criteria (Table F values of the *Guideline*) and 2) the MOE soil effects-based criteria (Table A values of the *Guideline*) for Ni, Cu, and Co. Excedence of Ontario soil background Table F *Guidelines* is an indication that soil concentrations for a given chemical parameter are above that which would be expected from natural geological processes and normal human activity, and the area has likely been influenced by a known point source of emissions. Excedence of the MOE soil remediation Table A *Guidelines* means that soil remediation may be required for any parcel of land in the impacted area undergoing development which involves a change in land use.

8.0 Methodology

8.1 Soil Survey

Phytotoxicology staff conducted the soil investigation during the periods of June 11th to June 12th, June 22nd to June 24th and July 9th, 1998. Where possible, 35 soil sites from the 1991 investigation were re-sampled. The 1991 investigation was, in turn, expanded from earlier surveys which consisted of 24 inner city sites. In the 1998 investigation, two of the sites sampled in 1991 (Sites 18 and 21) could not be re-sampled due to land use changes. It was not always possible to determine the exact locations sampled at each site in 1991, because the previous sites were not geo-referenced and subtle changes in land use can change the appearance of sites in relation to the hand-drawn maps prepared for site re-location. In those situations, soil was sampled in the same general area where the previous site was believed to have existed. Because the exact same site was not necessarily re-sampled, the 1991 soil data cannot be directly compared with the 1998 data on a site by site basis.

For the 1998 soil investigation, an additional 54 sites were established in a grid in the region around Port Colborne to more accurately define the spatial extent of potential contamination beyond the area covered in the 1991 investigation. Selected sites included street boulevards, residential lawns, parks, right-of-ways, commercial lawns, as well as a cemetery and a woodlot. The grid of new sample sites extended 9.5 km north to Welland, 9.5 km east to Pleasant Beach, and to the west as far as Burnaby (9.5 km). The furthest sites from INCO were located 13 km northeast in the area of Durbiat Rd. and Netherby Rd.

In total, surface soil (0-5 cm depth) was collected at 89 sites in the 1998 investigation. Sub-surface soil was collected at two additional depths (5-10 cm and 10-15 cm) at 23 of the 89 sites in the sample grid and included the 10 sites that were sampled at depth (5-10 cm) in the 1991 investigation. Three of the new soil profile sites were set along a transect to the west of the refinery, the remaining soil profile sites were set up to the east and northeast of INCO. Sample sites established in the region around Port Colborne are shown in Map 1. Sites sampled only for surface soil (0-5 cm depth) are indicated by circles (green on the colour map); sites where soil profiles (0-5 cm, 5-10 cm, and 10-15 cm) were sampled are indicated by (red) squares. The more intensive network of sample sites in or near the Port Colborne city core are shown in Map 2. The Port Colborne city map is set at a larger scale to show sample sites in proximity to INCO in better detail, as these sites tend to be closer together. Details of the sample sites (description, depth of sampling, and location relative to local roads and landscape features) are summarized in Table 1. Included in Table 1 are the UTM co-ordinates for each site. These geo-referenced co-ordinates were obtained with a Garmin 12XL satellite global position system.

All soil samples were collected in duplicate using standard Phytotoxicology field protocols [Ref.10]. This involved using a soil coring device which cuts a cylindrical core, two centimeters in diameter, to the depth to which the corer is inserted. Each sample consisted of approximately 30 cores taken throughout the designated sampling area. Soil cores were placed directly into a labeled polyethylene bag.

8.2 Cultivated vs. Uncultivated Sites

Previous Phytotoxicology investigations clearly indicated that the surface soil to the northeast of INCO was significantly contaminated with Ni, Cu, and Co. This area is largely agricultural, and standard agricultural practice is to till the soil in preparation for annual crop production. In an undisturbed soil profile the soil metal levels would be highest in the surface few centimeters and decrease rapidly with depth, because the contaminant is deposited from the air onto the soil surface. In order to assess the impact of agricultural practices on the distribution of Ni, Cu, and Co concentrations in the soil profile, soil samples were collected from adjacent untilled and tilled sites at four farm properties situated along a northeast transect at increasing distances from INCO. The first farm property, Farm (A), was located north of Killaly Rd. and east of Elizabeth St., the second farm property, Farm (B), was located north of the second concession line at Babion Rd. and Chippiwa Rd., Farm (C) was located on Miller Rd. midway between the third concession line and Forke Rd., and Farm (D) was situated on Brookfield Rd. near the Town Line overpass.

With the exception of Farm A, duplicate soil samples were collected using the standard Phytotoxicology soil coring device used in the general Port Colborne soil investigation. At each site, a total of fifteen soil cores were sampled to a depth of 30 cm. The cores were divided into six 5cm increments and each increment was placed in separate labeled polyethylene bags (i.e. 0-5 cm, 5-10 cm, 10-15 cm, 15-20 cm, 20-25 cm, and 25-30 cm). However, it was necessary to use an alternative method of sampling at Farm (A) because the ground was too hard to allow for the use of the soil corer to the required 30 cm depth. Two pits were dug to a depth of 30 cm in both the untilled and tilled sites at Farm (A). For each pit, soil was sampled in 5 cm increments from one of the pit walls using a trowel and each increment was placed into separate labeled polyethylene bags. Locations of the tilled and untilled sample sites are shown in Maps 1 and 2 as (yellow) triangles. Details concerning sample site identification are summarized in Table 2.

8.3 Sample Preparation and Analysis

Soil samples were processed at the Phytotoxicology sample processing laboratory (air-dried, homogenized, ground, sieved to a 355 micron size fraction, and stored in glass jars) using standard Phytotoxicology protocols [Ref.11]. Samples were then forwarded to the MOE Laboratory Services Branch for analysis of trace metals on a dry weight basis by inductively-coupled plasma-atomic emission spectrometry (ICP-AES) for total aluminum (Al), barium (Ba), beryllium (Be), calcium (Ca), cadmium (Cd), cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb) , strontium (Sr), vanadium (V), and zinc (Zn).

8.4 Data Analysis, Presentation and Interpretation

Soil analytical results for each of the 17 inorganic elements were compared to Ontario soil background concentrations for non-agricultural soils (Table F *Guidelines*). These values represent the expected distribution of chemical concentrations resulting from natural geological processes and normal human activity remote from the influence of known point sources of emissions. For those inorganic elements for which there is no Table F *Guideline* (i.e. Al, Ca, Fe, Mg, Mn, Sr), MOE "Ontario Typical Range" (OTR) guidelines were utilized for comparative purposes. The OTRs are a province-wide background-based set of guidelines derived for a large number of inorganic elements and organic compounds (see Appendix B). Table F *Guidelines* are based on the OTRs. In addition, the analytical results were also compared with the effects-based Table A *Guidelines* for residential/parkland land uses.

For this soil investigation, Table A criteria for medium/fine textured soils were utilized as they are more appropriate for the fine textured soils encountered during the survey than the generic criteria for coarse textured soils. Table A criteria apply to potable groundwater situations (i.e. drinking water is obtained from a groundwater aquifer), which applies to most of the area of Port Colborne outside of the city core. Some areas in the investigation may be served by a municipal drinking water supply that does not rely on the local groundwater. Table B *Guideline* criteria would apply to such sites but only if present or future groundwater (or surface water) sources of drinking water will not be adversely affected, including water for agricultural uses. For inorganic elements, the MOE Table A and B *Guideline* criteria are identical. Therefore, Table A criteria will be referenced throughout this report for all sites regardless of the groundwater situation at a particular site.

8.5 Contour Maps

Contaminant contour maps were produced from the surface soil chemistry data (0-5 cm depth) for Ni, Cu, and Co based on all of the 89 investigation sites. The surface soil data from the untilled sites at the four farm properties along the northeast transect were included in the mapping exercise. Two software packages were used to generate the maps. The data analysis and creation of the concentration contours was done using SURFER (Version 6.03 for Windows 95, by Golden Software Inc.). The output from SURFER was then imported into ARCVIEW GIS (Version 3.1, by Environmental Systems Research Institute, Inc.) and combined with base maps, roads, and water bodies to produce the final maps. Details concerning the process used to generate Maps 3 to 8 are provided in Appendix D.

These maps are statistical approximations of the spatial distribution of the different contaminants. Soil concentrations are only known with certainty at those sites for which soil was actually sampled and chemically analyzed. The contours produced by the program are significantly affected by the spatial distribution of the sampling sites, the accuracy of the position information of the sampling sites, and the program options used to generate the contours. The accuracy of the contours diminishes at the edges of the map and in large areas where there are no or very few sample sites. The maps should, therefore, only be used as an interpretive tool to provide information on approximate areas and/or patterns of contamination and cannot be used to infer concentrations of

contaminants at locations not directly sampled.

9.0 Results

9.1 Analytical Data

The results for the chemical analysis for 17 inorganic elements in soil collected from the 1998 survey sites in the Port Colborne area are summarized in Appendices A1 to A17. Data for all survey sites and sampling depths are provided in these appendices as well as sampling results for tilled and untilled sites situated on the four farm properties. All data are the average of duplicate samples in $\mu g/g$ air-dry weight, with two exceptions. Analytical results for Cu from one of the duplicate soil samples collected from the residential yard at Site 59 were rejected as were data from one of the untilled duplicate pits sampled at Site 157. The rationales for rejecting these data are discussed later in the report.

In each appendix, values shown in bold face exceed the corresponding non-agricultural Table F soil background *Guideline*. For those inorganic elements for which Table F criteria have not been established (e.g. Al, Ca, Fe, Mg, Mn, Sr), the rural OTR was used as an indicator of expected soil background concentration. Data in shaded cells exceed the effects-based Table A soil *Guideline*.

9.1.1 Soil Nickel

The soil Ni data are summarized in Appendix A1. Nickel concentrations in surface soil (0-5 cm) exceeded the Table F *Guideline* for non-agricultural land use (43 $\mu g/g$) at 70 of the 89 survey sites (results for tilled sites vs. untilled sites not included). Soil Ni concentrations throughout the Port Colborne area were substantially higher than background, ranging up to more than 5,000 $\mu g/g$ (Site 24). The Table A *Guideline* for Ni (200 $\mu g/g$) was exceeded at 27 sites; the furthest being 5.6 km northeast of INCO. Also, results for the soil profile sites indicated that where surface soil Ni exceeds the Table F *Guideline*, soil Ni concentrations in the 5-10 cm and 10-15 cm depth samples were also above the Table F value. Similarly, for those soil profiles where the 0-5 cm sample exceeded the Table A *Guideline*, the Table A criterion is exceeded at the 5-10 cm depth, and in many cases, at the 10-15 cm sample depth as well. These data indicate that at sites where the surface soil has not been disturbed Ni from historic atmospheric deposition has not remained at the soil surface but has moved down through the soil profile over time to a depth of at least 15 cm.

9.1.2 Soil Cobalt

The soil Co data are summarized Appendix A2. Cobalt concentrations in surface soil (0-5 cm) exceeded the Table F *Guideline* for non-agricultural land use (21 $\mu g/g$) at 13 of the 89 survey sites; all of these sites being within 2 km of INCO. The two highest Co concentrations occurred at Site 1 (195 $\mu g/g$) and Site 24 (105 $\mu g/g$) which are both located immediately to the northwest of INCO in very close proximity to the refinery; i.e. distances of 305 m and 372 m respectively. The Table A *Guideline* for Co (50 $\mu g/g$) was exceeded at six of the sites, the furthest site being approximately 2 km northeast of INCO, which is less than half the distance at which soil Ni was observed to exceed it's corresponding Table A criterion.

Where Co concentrations exceeded the Table F criterion in surface soil, soil Co concentrations at the 5-10 cm depth, and in most cases the 10-15 cm depth, also exceeded the Table F *Guideline* (e.g. soil profile Sites 3, 4 and 11). These data demonstrate that like Ni, Co has moved down through the soil over time. At each of the sites where the Table F or Table A soil *Guidelines* for Co were exceeded the soil Ni *Guidelines* were also exceeded. These analytical results demonstrate that Co and Ni are co-contaminants in soil and have originated from the same source.

9.1.3 Soil Copper

The soil Cu data are summarized in Appendix A3. The Cu results for one of the replicate samples collected at Site 59 (0-5 cm, 4,497 m northwest of INCO) were rejected on the basis that the very high soil Cu value was inconsistent with the corresponding Ni and Co values for it to have originated from emissions from the refinery. The soil Cu concentration in this one replicate was four times the soil Ni concentration in the same sample. In contrast, the soil Cu concentration for the duplicate sample taken at this site was within expected soil background concentrations. In addition, analytical results for other sites to the northwest but located in closer proximity to the City of Port Colborne and INCO had soil Cu concentrations that were all below the non-agricultural Table F *Guideline* (85 μg/g). It is likely that the Cu contamination detected in the single replicate resulted from activities at the residence and is not associated with historic INCO emissions.

Copper concentrations in surface soil (0-5 cm) exceeded the Table F *Guideline* for non-agricultural land use (85 μg/g) at 13 of the 89 survey sites. The Table A *Guideline* for Cu (300 μg/g) was exceeded at four sites, all located to the northeast of INCO. The two highest soil Cu concentrations occurred at Site 24 (350 μg/g) and Site 150 (355 μg/g) located 304 m and 1,745 m northeast of INCO, respectively. Like Ni and Co, the soil profile data indicated that Cu *Guideline* exceedences in surface soil usually resulted in *Guideline* exceedences in the deeper soil samples as well. Also, the soil Cu concentrations were clearly related to both Co and Ni values in soil at the same sample sites, indicating all three elements originated from the same source.

9.1.4 Other Inorganic Elements

The soil Al, Ba, Be, Cd, Ca, Cr, Fe, Pb, Mg, Mn, Mo, Sr, V and Zn data are summarized in Appendices A4 through A17, respectively. Soil Mn (Appendix 13) and V (Appendix 16) concentrations were within the expected background range at all sample sites. For the remaining inorganic elements, soil concentrations exceeded Table F or OTR_{98} guidelines at one or more sites in the Port Colborne survey area. Based on the random distribution of the various exceedences and knowledge of the INCO refinery process there is no reason to suspect these exceedences are related to INCO emissions.

Soil Sr (Appendix 15) concentrations exceeded the background-based OTR guideline at 29 sites across the sampling area. However, there is no consistent spacial relationship between soil Sr concentrations and proximity to INCO and Sr is not associated with INCO emissions. The unusually high number of OTR exceedences for Sr suggests that soil Sr concentrations in the Port Colborne area are, on average, marginally higher then the normal range of Sr in soil elsewhere in the province.

Lead (Appendix 11) and Zn (Appendix 17) concentrations also exceeded their respective Table F *Guidelines* at several sites. Soil Zn concentrations were elevated at all four sites in close proximity to INCO (Sites 1,2, 3 and 4). There is a possibility that marginally elevated Zn in soil may be related in some way to fugitive emissions from the INCO site, but not with stack emissions. The Table A criterion for Pb (200 μg/g) was exceeded at two residential sites, Site 150 located 1,745 m northeast INCO, and Site 83 located approximately 8 km northeast of INCO. However, it is not uncommon for properties in older urban communities to have elevated soil metal levels resulting from various domestic sources (e.g. galvanized fencing, car exhaust, peeling paint, etc.).

The Table A *Guideline* for Be (1.2 μg/g) was exceeded in depth samples at Site 64, located more than 7.6 km northeast of INCO, as well as Sites 164 and 165, which are a pair of untilled and tilled sites located over 11 km northeast of INCO. A recent province-wide study conducted by the Phytotoxicology Section [Ref 12] revealed that certain shale materials contain high naturally-occurring Be concentrations (up to 4 μg/g). It is very likely that the scattered elevated Be concentrations detected at a few sites in the Port Colborne area are associated with shale materials.

10.0 Discussion

10.1 Soil Nickel

It is apparent from the analytical results that there is considerable variability in soil Ni concentrations vs. distance from INCO. Soil Ni concentrations at some sites are uncharacteristically low relative to other sites located at similar or greater distances from the refinery. For example, the surface soil Ni concentration at Site 10 (approximately 1,400 m northeast of INCO) was 21 μg/g, which is in the range expected for soil background. Soil Ni concentrations at sites located around Site 10 were orders of magnitude higher, as expected based on the proximity to INCO.

This investigation covers a very large urban and rural area that has been impacted by emissions from the INCO refinery over a very long time, followed by a period of 15 years during which there were no stack emissions and likely only marginal fugitive emissions. Sample sites were chosen that appeared to the investigators to be undisturbed or were selected based on information provided by property owners confirming the undisturbed status of the site. Unfortunately site disturbance is often not evident or a property owner may not be aware of changes to the property that occurred before their tenure. The addition of sod or topsoil or similar landscaping activities places clean soil overtop of the metal contaminated soil, and since the sampling procedure at most sites included only surface soil sampling (0 to 5 cm) the resultant sample would have low metal levels and the contaminant burden at that site is underestimated.

The highest soil Ni concentration (5,050 μg/g) was detected at Site 24, which is located in close proximity to the INCO property (approximately 300 m northwest). Figure 1 shows the distribution of Ni in surface soil (0-5cm) collected from all survey sites located in the quadrant to the northeast of INCO vs. increased distance from the refinery. Figure 2 shows the soil Ni distribution for all sites located in the northwest quadrant. In each figure a regression line was fit to the data to estimate the slope of the soil Ni gradient in each quadrant. The regression line of best fit (i.e. which provided an r^2 of highest value) was derived by calculating the least squares fit to the set of points using the following power equation: $y = cx^b$ (where b and c are constants). Similar

regression lines were fit to the Cu and Co soil data.

Comparing Figures 1 and 2, the concentration gradient is steeper in the northwest quadrant than the northeast quadrant, with the soil Ni levels falling off exponentially within 1 km of the INCO stack to the northwest. The highest soil Ni concentrations in the northeast quadrant are clustered approximately 2 km downwind of INCO. Due to stack and airflow dynamics, it is not uncommon for contaminant levels in soil to peak some distance downwind of a tall stack in the direction of prevailing winds. The non-snow season prevailing winds are from the west-southwest of the Port Colborne area, which would skew the metal fallout to the east-northeast, which is exactly what was observed. Beyond about 1 km to the northwest and about 2 km to the northeast the soil Ni levels decrease substantially but do not reach background concentrations for several more kms in the northwest direction, and not at all in the sample sites farthest northeast.

A clearer picture of the spatial distribution of Ni in surface soil (0-5 cm) across the Port Colborne area is provided by Map 3. Soil Ni contours are designed to identify Table F and Table A *Guidelines* and illustrate the exponential nature of the contamination, so the contour intervals are not uniform. From this map, the highest soil Ni concentrations (between 4,000 and 5,000 μg/g) occur in very close proximity to INCO in the area of Kinnear St. between Mitchel and Davis Sts. However, a second contour island of very high soil Ni (>3,000 μg/g) also occurs centred around Site 150 about 1.7 km north-northeast of INCO in the Killaly and Elizabeth Sts. area. This illustrates the bimodal deposition pattern that is not uncommon with tall stack dynamics.

Surrounding these two "hot spots" is the contour for soil Ni exceeding 2,000 μg/g, which extends all the way from the intersection of Rodney St. and Fares St. to the northeast of INCO beyond the intersection at Killaly St. and Snider Rd., a distance of about 2.5 km. Soil Ni levels in this area of Port Colborne are likely to be an order of magnitude above the Table A *Guideline*. The remaining contours show that soil Ni concentrations decline very rapidly to the west and northwest of INCO but decline much more slowly in the east and northeast directions.

The 200-500 μg/g contour interval is significant because it corresponds to the effects-based Table A *Guideline*. This contour extends in a northeast direction to approximately Miller Rd. north of Hwy 3 and then appears again as an island in the area centred on the second concession between Lorraine Rd. and Whites Rd. This anomaly can be attributed to Ni soil concentrations exceeding 300 μg/g at Sites 62 and 63 but falling to145 μg/g at Site 50 (residential property) and only 78 μg/g at Site 12 (a right-of-way), which both lie between INCO and Sites 62 and 63. In 1991 Site 12 had a soil Ni concentration of 360 μg/g, but when the site was re-sampled in 1998 the soil Ni level was 78 μg/g. Although not apparent to the investigator at the time of sampling, this site has almost certainly been disturbed. As a result of the data collected from Sites 62 and 63 and the lack of other sampling points in the immediate area, the contour mapping program created the apparent 200-500 μg/g contour island. It is possible that soil Ni concentrations exceed the Table A soil *Guideline* over a larger area than is illustrated by the 200-500 μg/g contour. Additional sampling is warranted in the area between Sites 12 and 50, and Sites 62 and 63 so that the contaminant contours can be more accurately defined. A similar situation occurs for the 100-200 μg/g contour interval whereby a contour island is created around Site 73 to the northwest because the soil Ni concentration at Site 60, which lies between Site 73 and INCO to the southeast, falls just below 100 μg/g (e.g. 92 μg/g). In this case the contour mapping program likely over estimates the area of the 100-200 μg/g Ni

contour.

Soil Ni concentrations fall below the Ontario soil background concentration (Table F *Guideline* of 43 μg/g) at approximately 8 km west and northwest of INCO. Similarly, soil Ni background levels occurred about 9 km to the north and 11 km to the east of INCO. Since background concentrations were achieved at sites in these directions the computer generated contours are likely quite accurate in regards to the spatial distribution of soil Ni concentrations in the Port Colborne area to the west, north, and east of INCO. However, background Ni concentrations were not achieved even at a distance of 13 km in a northeast direction, the direction of prevailing winds. The sites farthest downwind of INCO (Sites 68, 69 and 87) had surface soil Ni concentrations of 73, 63, and 53 μg/g respectively. The northeast contour boundary that appears on Map 3 is an estimate of the actual extent generated by the mapping program. The area that exceeds the Table F soil background concentration may extend much further into the municipality of Fort Erie. Therefore, as was the case in the Phytotoxicology investigation conducted in 1991, the sampling strategy in the 1998 survey was not adequate to determine the total extent of soil Ni contamination in the region surrounding Port Colborne - it didn't go far enough to the northeast.

10.2 Soil Copper

Figure 3 illustrates the distribution of Cu in surface soil (0-5 cm) collected from all survey sites located in the quadrant to the northeast of INCO vs. increased distance from the source. The distribution of Cu in surface soil for all sites located in the northwest quadrant is illustrated in Figure 4. As with Ni, a regression line was fit to the data to estimate the slope of the soil Cu gradient. The gradients are very similar to those for Ni, whereby the gradient is steeper in the northwest quadrant than the northeast quadrant. The highest soil Cu concentrations in the northwest quadrant occurred less than 400 m from the refinery (Site 1, 325 μg/g, 372m northwest, Site 24, 350 μg/g, 304 m northwest). Like Ni, the highest soil Cu concentrations in the northeast quadrant are clustered approximately 2 km downwind of INCO. For example, the highest surface soil Cu concentration to the northeast (355 μg/g) occurred at Site 150, which is 1.7 km northeast of INCO. In both the northeast and northwest quadrants, soil Cu concentrations declined rapidly with increasing distance from the refinery.

The spatial distribution of Cu in surface soil (0-5 cm) in the Port Colborne area is illustrated in Map 4. The highest contour interval (300 to 350 μg/g) coincides with the effects-based Table A *Guideline* for Cu (300 μg/g) and occurred in very close proximity to INCO in the vicinity of Kinnear St. and Davis St. A second contour island of soil Cu concentration in excess of the Table A *Guideline* occurred at the same location as the highest soil Ni contour, approximately 2 km northeast of INCO. This contour is driven by data obtained from survey Site 150, which is located northeast of Killaly Rd. and Elizabeth St. A similar bimodal pattern appears for the 250-300 μg/g Cu contour. The 200-250 μg/g contour could almost be superimposed on the 2,000-3,000 μg/g Ni contour. The remaining contours illustrate that soil Cu concentrations declined very rapidly to the west and northwest of INCO but much more gradually in the east and northeast directions.

The contour area estimated to exceed the background-based Table F soil *Guideline* concentration for Cu (85 μg/g) extends west to the Welland canal and beyond the canal to Elm St.

in the southwest direction. The computer generated contour shows that soil Cu concentrations exceeded background levels in an easterly direction to a point midway between Lorraine Rd. and Weaver Rd., beyond Killaly St. to as far north as Russell St. and Wellington St, and past Hwy 3 in a northeasterly direction to about 3.5 km from INCO. Since background concentrations were achieved at sample sites in all directions the computer generated contours are likely quite accurate in regards to the spatial distribution of soil Cu in the Port Colborne area.

10.3 Soil Cobalt

As shown in Figures 5 and 6, the surface soil Co gradient is much steeper in the northwest quadrant compared to the northeast quadrant. The two highest soil Co concentrations occur at Site 1 (195 μg/g) and Site 24 (105 μg/g) which are both located immediately to the northwest of INCO. Like Ni and Cu, the highest soil Co concentrations in the northeast quadrant are clustered approximately 2 km downwind from INCO but at much lower concentrations than occur to the northwest of the refinery. Soil Co concentrations decline slowly with increased distance from INCO in both quadrants.

The distribution of Co in surface soil (0-5 cm) in the Port Colborne area is illustrated in Map 5. There is a very clear concentration gradient relative to INCO. Based on the computer-generated map the highest soil Co concentrations (greater than 100 μg/g) are centred in the neighbourhood immediately to the northwest of INCO in the vicinity of Davis St. and Kinnear St. The next contour for soil Co concentrations exceeding 50 μg/g (Table A *Guideline*) extends in a northeast direction from south of the intersection of Fares St. and Rodney St. well past Killaly St. east as far as Snider Rd., approximately 2.5 km from INCO. The shape and area determined by this contour coincides with and can almost be superimposed on the 2,000 μg/g contour for soil Ni (see Map 3).

The contour area estimated to exceed the Table F soil background *Guideline* for Co (21 μg/g) is very similar in shape and extent as the Table F contour for Cu, except that it does not extend as far in either a southerly or westerly direction. Soil Co concentrations exceed Table F in an easterly direction to the area between Lorraine Rd. and Weaver Rd. and to the north past Hwy 3 to the northeast as far as 3.5 km from the refinery. The soil Co concentrations fall below the Table F background concentration beyond this contour. Since background concentrations were achieved at sample sites in all directions, the computer generated contours are likely quite accurate in regards to the spatial distribution of soil Co concentrations in the Port Colborne area.

10.4 Nickel, Cobalt and Copper Concentrations vs. Soil Depth

The analytical results from the 23 soil profile sites indicate that where surface soil Ni concentrations exceed Table F or Table A criteria, soil Ni concentrations at the 5-10 cm and 10-15 cm sample depths also exceed these criteria (refer to Appendix A1). This trend is also evident for both Cu and Co (refer to Appendices A2 and A3). For some soil profiles soil contaminant concentrations are higher at the 5-10 cm and 10-15 cm depths than at the surface (0-5 cm). For example, at Site 4 (located 675 m northwest of the refinery), the highest Ni, Cu, and Co concentrations occur at the 10-15 cm depth. In fact, soil Cu and Co concentrations also exceed their

corresponding Table A criterion at this depth.

This observation is not unusual in urban sites which have been exposed to contaminants for a long period of time followed by a period of reduced or no deposition. Depending on soil characteristics, such as texture and organic matter content, contaminants can move down through the soil profile over time as a result of rainwater percolation and be mixed by soil organisms. Common landscaping practices, such as adding topsoil and re-sodding lawns in residential communities, can significantly reduce surface soil metal concentrations at these properties, with the result that soil contaminant levels further down in a soil profile can substantially exceed surface concentrations. The same trend has been observed for Pb in soil near Toronto roadways in the period since Pb has been removed from gasoline.

Due to the small number and a northeast bias in the locations of the soil profile sites, meaningful contour maps for Ni, Cu, and Co soil concentrations at depth could not be produced. Instead, the contaminant depth profile data are summarized in Table 3. In this table, mean soil concentration (and range of concentrations) for Ni, Co, and Cu, are shown for each of the three sample depths for all the soil profile sites in areas where, based on the contaminant contour maps, the soil concentrations were either above or below the Table A criteria.

The first area includes the area of Port Colborne where surface soil Ni concentrations (0-5 cm depth) were estimated to exceed the Table A *Guideline*. Soil profile Sites 3, 4, 11, 14, 17, 37, 43, 51, 62, and 63 were included in the calculation of mean values for this area. The second area includes that portion of Port Colborne where soil Ni concentrations were estimated to be below the Table A criterion. Soil profile Sites 12, 19, 33, 39, 45, 49, 50, 53, 55, 72, 84, 86, and 89 were included in determining mean values for this second area. Mean soil concentrations for Ni, Co, and Cu, calculated for the three sample depths, are also shown as histograms in Figures 7, 8 and 9, respectively.

There is a considerable range in soil Ni concentrations in the area where surface Ni concentrations exceed the Table A criterion for the three sample depths at the ten soil profile sites. Nevertheless, the mean soil Ni level for each depth suggests that the overall trend is a decline in soil Ni concentrations with increased depth. This pattern of decreasing soil Ni concentration with increasing depth is expected in areas where the source of contamination is historic atmospheric deposition. The mean soil Ni concentration remains well above the Table A *Guideline* throughout the soil profile to the full depth of sampling (15 cm) suggesting that a great deal of the Ni has moved from the surface down through the soil profile over time.

It is likely that significant Ni contamination extends beyond the 15 cm depth throughout this area. This may have a significant impact on soil remediation carried out in this area, as the contamination is not restricted just to surface soil. Additional sampling is warranted to determine the actual depth to which elevated levels of Ni have migrated in the soil in the Port Colborne area. Based on very limited data from tilled vs untilled sites, which was carried out as part of this study, soil Ni concentrations could exceed the Table A criterion to at least 30 cm at some sites within this area.

Like Ni, there is a considerable range in soil Co and Cu concentrations in the ten soil profile

sites grouped in the two areas (above and below Table A criteria). The mean soil Co and Cu concentrations for each of the three sample depths are significantly lower than the corresponding soil Ni levels, but like Ni, a decline in soil concentrations with increased soil depth is evident for both these metals (refer to Table 3 and Figures 8 and 9). These data also suggest that on average, these two metals have generally not moved as far down in the soil profile as Ni. The mean soil Co concentration falls below the Table F *Guideline* at the 5-10 cm depth, whereas the mean soil Cu concentration exceeds the Table F criterion at the 5-10 cm depth but falls below the Table F value at the 10-15 cm sample depth.

In the area of Port Colborne where the contour maps predict that surface soil Ni concentrations do not exceed Table A, the mean Ni concentration based on data from 13 soil profile sites remains above the Table F criterion at all three sample depths. Based on the means, the general trend is a slight increase in soil Ni concentrations with depth. Natural soil processes could account for this trend. In this area, which lies beyond the high deposition zone, Ni that has accumulated in surface soil from historic emissions appears to be moving down through the soil profile over time. Soil Ni concentrations at sites located within this area may exceed the Table F Guideline beyond the 15 cm sample depth. In contrast, the mean soil Co and Cu concentrations do not exceed their corresponding Table F criteria at any of the three sample depths. This is to be expected since substantial Co or Cu contamination was shown not to extend into the area where surface soil Ni concentrations were below the Table A criterion (based on contour mapping results).

10.5 Tilled vs. Untilled Sites

As part of the 1998 survey, a study was undertaken to assess the potential impact of agricultural practices on the distribution of Ni, Cu, and Co in soil in the Port Colborne area. The effects of tillage on the distribution of these three metals in soil at four farm properties situated at increasing distances along a northeast transect from INCO are summarized in Table 4. The data for Ni, Co and Cu are also presented schematically in Figures 10, 12, and 13 respectively. It should noted that it was necessary to reject the data from one of the two pits of the untilled site at Farm A. Inconsistencies in the analytical results obtained for the 20-25 cm and 25-30 cm depth samples could not be explained rationally. Nickel, Co, and Cu, as well as other inorganic elements such as Pb were extremely high compared to the analytical results obtained from soil sampled at the surface and at intermediate depths in the soil profile, as well as analytical results for corresponding horizons in the duplicate pit. On closer examination of the sample after analyses had been performed, the soil at these depths appeared to be darker in colour than other horizons sampled in either of the two pits. This anomaly raised questions about whether the pit in question met the criteria for an undisturbed site and for this reason the data was rejected.

Looking first at the Ni data in Table 4, the soil Ni concentrations in both the untilled and tilled soil profiles at Farm A, which is located less than 2 km to the northeast of INCO, exceed the Table A soil remediation criterion down to the 20-25cm sample depth. The 25-30 cm samples also exceeded the Table F soil background concentrations. Thus, a sampling depth of 30 cm was insufficient to determine the depth to which Ni contamination from historic emissions has raised soil to above expected soil background concentrations.

The soil Ni concentration in the untilled soil profile is considerably higher in the 5-10 cm depth sample (1,700 μg/g) than the 0-5 cm depth sample (1,100 μg/g) suggesting that either the Ni has moved down through the profile over time as a result of soil processes or the surface has been disturbed in some way to reduce the surface Ni concentration. Below the 5-10 cm depth sample, soil Ni declines with increased depth, which is to be expected for soils impacted by atmospheric deposition over time. By comparison, the soil Ni concentration in the tilled site remains the same (1,100 μg/g) from the surface soil sample (0-5 cm) through to the (15-20 cm) depth sample, dropping off only slightly at the 20-25cm depth (840 μg/g). The soil Ni concentration at 20-25 cm deep is almost twice as high in tilled soil then untilled soil (840 μg/g vs 460 μg/g). The soil Ni concentration at the 25-30 cm depth sample is also higher in the tilled site (138 μg/g) vs. the untilled site (110 μg/g). Both soil concentrations at this depth exceed the Table F soil background value.

Cultivation would be expected to have a dilution effect if the metal contamination was confined to the surface soil only. Contaminated soil at the surface would be mixed with less-contaminated sub-surface soil diluting the Ni to much lower concentrations through the soil profile. Significant dilution of soil Ni has not occurred at the tilled site at Farm A because the Ni contamination has extended beyond the depth of cultivation at this site. Tilling at this site has resulted in soil Ni concentrations becoming more homogenous through the soil profile, so that the Ni concentrations remain well above the Table A soil remediation criterion to a depth of 25cm. This trend is equally apparent in the soil Cu and Co data for Farm A. Like Ni, soil Cu and Co concentrations remain elevated through the top 20 to 25 cm, then decline with depth to background levels at the 25-30 cm depth.

Farms B, C and D are each located along the northeast transect at increasingly greater distances from INCO than Farm A. For this reason, soil Ni, Co and Cu concentrations in the untilled and tilled sites are significantly lower. Even at these greater distances, soil Ni concentrations still exceed the Table F soil background values to depth. By comparison, soil Cu and Co concentrations are in the expected background range at each of the six sampling depths in both the untilled and tilled sites on these three farm properties (refer to Table 4). This is to be expected because each of these three farm properties lie beyond the zone of Co and Cu contamination, as determined by contour Maps 4 and 5.

At Farm B, which is the next property along the transect, 4.6 km northeast of INCO, soil Ni exceeds the Table F background criterion to the 20-25cm sample depth. Soil Ni occurs at background levels at the 25-30 cm depth in both the untilled and tilled sites. However, the soil Ni concentrations at each sample depth do not appear to differ significantly between the untilled and tilled sites. Therefore, tilling didn't appear to have a significant impact on soil metal levels at this farm. This may be due to the soil Ni contamination extending beyond the depth of cultivation at this site which would limit the amount of uncontaminated sub-soil for mixing during tillage.

The results from Farms C and D indicate that soil Ni concentrations appear to be lower at each of the six sample depths in the tilled sites compared to the same sample depths at the corresponding untilled sites. The results from Farm C indicate that soil Ni concentrations in the untilled site exceed the Table F criterion to greater depths (20-25cm) than in the corresponding tilled site (10-15cm). For Farm D, whereby soil Ni exceeds the Table F background value to the 10-15cm depth in the untilled site, soil Ni in the tilled site is below the Table F value throughout the soil

profile. At these two farthest farm sites soil cultivation appears to have diluted the soil Ni concentrations at least to a depth of 15cm.

10.6 Comparison with Historical Data

Tables 5, 6, and 7 compare soil Ni, Co, and Cu concentrations from 16 common sample sites at four points in time from 1974 to 1998. Initially it was thought that this historic data would be useful in identifying contaminant trends with time, because soil was collected at the same sample sites over a 24 year period. However, the data in Tables 5, 6, and 7 do not indicate a consistent trend. For example, Site 2292014 (Table 5) had a surface soil (0-5 cm) Ni concentration in 1974 of 433 μg/g, which increased to 6,000 μg/g in 1991, and subsequently fell to 585 μg/g in 1998. There are two factors that make a common site comparison through time potentially unreliable. The first is the inability to identify and re-sample precisely the same spot. The practice of geo-referencing sample sites using a GPS is recent, previously the sample site was described with a hand drawn map and/or a written description. In some cases these maps and descriptions were either inaccurate or provided only marginal detail. For example a street co-ordinate may have been provided but precisely what side of the street or which corner was sampled may not have been indicated. The second factor is that a site could have been landscaped or remediated and the change may not be evident, so that the same site is re-sampled but the soil is not the same. It is evident that unless precisely the same spot can be re-sampled and assurances can be provided that the site has not been remediated then comparisons through time of individual sample sites can be unreliable. A consistent network of accurately identified sample sites are required to obtain reliable data on contaminant change through time. Since the data are obviously inconsistent, further discussion of these results is not warranted.

11.0 Implications of Contamination

11.1 Total Areas Estimated to Exceed Table F and Table A Guideline Values for Nickel, Copper, and Cobalt.

The data from this survey were used to produce concentration contour maps for the distribution of Ni, Cu, and Co in surface soil (0-5 cm depth) as determined by Surfer/Arcview (Maps 3, 4, and 5). Three additional maps were produced for Ni, Cu and Co in order to display the two contour polygons that correspond to 1) the Ontario soil background concentrations (Table F), and 2) the MOE soil remediation concentrations (Table A, refer to Maps 6, 7 and 8). In each map, the area that exceeds the effects-based Table A criterion is shown in the colour red (dark shade), and the area that exceeds the background-based Table F criterion is shown in the colour yellow (light shade).

The surface areas represented by the Table A and F polygons for Ni, Cu and Co were calculated using a feature in Arcview and these calculated areas were converted to square kilometers. The calculated areas are provided in the legends of each of Maps 6, 7 and 8. It should be noted that in each map, the area designated as exceeding Table F only includes the polygon (in yellow-light shade) where the Table F criterion is exceeded but does not include the area of the polygon (in red-dark shade) that corresponds to the Table A guideline. The total area that exceeds Table F is obtained by summing the area calculated for the Table A polygon and the Table F polygon. The

areas calculated to have been impacted by historic emissions from INCO; i.e. which in 1998 contained surface soil (0-5 cm) that exceeds Table F and Table A soil criteria for Ni, Co, and Cu, as determined through the contour mapping program, are summarized in Table 8.

In Map 6 the polygon in red (dark shade) represents the total area in which the Ni concentration in surface soil (0-5cm) has been estimated to exceed the Table A soil remediation criterion using the Surfer/ArcView contour mapping program. The total area that exceeds the soil Ni Table F criterion goes beyond the scale of this map, therefore the estimate of 159 km^2 is a minimum value. The impacted area estimated to exceed the soil Ni Table A remediation criterion is approximately 19 km^2. The southern boundary of this impacted area extends along the Lake Erie shoreline from Sugarloaf Point west of the city to just east of Weaver Rd. almost as far as Pine Crest Point. Starting in the west, the boundary extends north from Sugarloaf Point through the adjacent neighbourhood up to Clarence St. and northward up the west side of the Welland Canal, cutting across the island just south of the turn in Mellamby Rd. and continues in a northeast direction past Hwy 3 and Snider Rd., extending as far as the intersection between Weaver Rd. and Hwy 3. A second polygon was also included in the area calculation for soil exceeding the Ni Table A remediation criterion. This area of impact is approximately 2.25 km long in a north-south direction, centred on the second concession and extends W beyond Miller Rd. to the east past White Rd. As previously mentioned, these polygons are statistical approximations only. Soil concentrations are known with certainty only at those sites for which soil was actually sampled.

Table 8: Estimate of Areas in 1998 that Exceed MOE Table F and Table A Soil Criteria as determined by Surfer/Arcview.

Port Colborne Area	Nickel	Copper	Cobalt
Area where 0-5 cm soil concentrations exceed background-based Table F criterion	>159 km^2*	8.9 km^2	6.1 km^2
Area where 0-5 cm soil concentrations exceed effects-based Table A criterion	19 km^2	0.3 km^2	1.6 km^2

* minimum estimated area, actual area may be larger, as sample sites farthest downwind did not reach background levels.

In Map 7, the polygons in red (dark shade) represent the total area in which surface soil Cu is estimated to exceed the Table A remediation criterion by the contour mapping program. The areas are small, one being centred around the intersection of Davis St. and Kinnear St., the second being located northeast of Killaly St. and Elizabeth St. The area estimated to exceed the Table A soil Cu criterion is 0.3 km^2. The area estimated to exceed the Table F soil background value for Cu is 8.9 km^2 and is represented in yellow (light shade). As previously described, this polygon extends to the

west of INCO past the Welland Canal to Elm St. in the southwest direction. The boundary extends to the north as far as Russell St. and Wellington St. and past Hwy 3 and Snider Rd. in a northeasterly direction to a point midway between Lorraine Rd. and Weaver Rd. to the east.

In Map 8, the total area estimated to exceed the Table A soil remediation criterion for Co is 1.6 km^2 and is marked in red (dark shade). This polygon, which is centered approximately on Durham St., extends in a north direction from south of the intersection at Fares St. and Rodney St. to Louis St. and Davis St., and then to the northeast across Durham St. well past the intersection of Killaly St. east and Snider Rd. The area that exceeds the Table F value has a total area of 6.1 km^2. Its boundaries extend from the Lake Erie shoreline to the south, to the Welland Canal in the west, and past Hwy 3 and Snider to the northeast, and between Lorraine and Weaver Sts. to the east.

11. 2 Phytotoxicity

The rationale for the MOE Table A criteria for Ni, Cu, and Co is the protection of plants, as all three elements are potentially phytotoxic at soil concentrations lower than those associated with an adverse health effect. Of these three contaminants Ni is the most potentially phytotoxic and cobalt is the least potentially phytotoxic at soil concentrations documented in Port Colborne. Nickel injury on street tree foliage in Port Colborne and on farm produce immediately east and northeast of the INCO refinery has been documented in previous Phytotoxicology reports. This historical injury was from a combination of Ni uptake from contaminated soil and Ni in the air. During the 1998 Phytotoxicology investigation Ni injury was observed on street tree foliage (mostly silver maple) in the area that roughly corresponds to the zone of soil nickel concentrations exceeding 2,000 $\mu g/g$, as illustrated in Map 3. This injury has to be related to uptake of Ni from soil, as INCO Ni emissions to the ambient air ceased in 1984.

There is consensus in the scientific literature that Ni is phytotoxic at high soil concentrations, but the dose-response relationships that indicate the concentrations at which injury can occur are very inconsistent. The MOE soil nickel Table A *Guideline* is set at 200 $\mu g/g$, which is the lowest observable effects concentration in studies that were documented sufficiently to allow the data to be confidently interpreted. Therefore, soil nickel concentrations in excess of 200 $\mu g/g$ have the potential to cause injury to sensitive species of plants. The injury may be in the form of reduced plant growth, reduced yield, or the development of foliar injury symptoms. The mechanism of Ni phytotoxicity is not precisely known, but it is suspected to be the replacement of Fe by Ni in some complex that is essential to normal plant metabolism. In other words, excessive Ni is believed to induce Fe deficiency in plants. Necrotic plant tissue is usually associated with elevated tissue Ni concentrations, while chlorotic leaves are usually found to be Fe deficient. Young plants tend to be more susceptible to Ni injury than older plants of the same species, making the problem of soil Ni contamination particularly acute for the agricultural community, which for the most part has an annual crop cycle.

There is a wide range in plant sensitivity to Ni. Cereal grains such as oat, barley, and ryegrass are amongst the most sensitive, woody deciduous plants and market garden crops are variable, ranging from moderately sensitive to moderately resistant, and hyper metal accumulators such as *Alyssum spp* are so resistant that Ni may possibly be an essential element for their growth.

Alyssum spp may have potential application for phytoremediation of metal contaminated soil.

The potential for soil contaminated with Ni to cause injury to plants is dependent on numerous soil physical and chemical characteristics and the concentration and type of Ni in the soil.

In order for Ni in the soil to cause plant injury it must be bioavailable, that is, it must be able to be dissolved in soil water so the plants can take it up through their root systems. Generally Ni is more available for plant uptake and therefore has a greater potential to be phytotoxic in soils that are more acidic (lower pH), have a lower organic matter content, have a lower cation exchange capacity, and are lighter-textured (sandy soils as opposed to clay soils). Nickel is rarely present as a pure element; it is commonly complexed in soil with other elements such as sulphur (S), Fe, Mn, and even Ca. Nickel complexed in this manner is significantly less bioavailable, and so less phytotoxic. These site specific soil factors are largely responsible for the lack of a linear relationship between soil Ni concentrations and observed effects on vegetation.

11.3 Health Risks Related to Soil Metal Contamination in Port Colborne.

As a result of the 1991 Phytotoxicology study [Ref.5] the MOE, in conjunction with the Region of Niagara Health Services Department, conducted a health risk assessment to determine if exposure to elevated soil Ni, Cu, and Co concentrations in Port Colborne may result in the potential for adverse health effects. The report from this study was completed and released in May 1997 (Ref.9). The following is a very brief overview of the health risk study and is provided here to tie together the issues of soil contamination identified as a result of the 1998 Phytotoxicology investigation, the growth and consumption of garden produce grown in contaminated soil, and the exposure to contaminated soil (ingestion, inhalation, dermal contact) as it relates to human health. The 1997 health risk study was based on environmental information obtained in the 1991 Phytotoxicology study. The 1998 Phytotoxicology study did not find any new or more serious soil contamination, it was simply more intensive and resulted in a more accurate understanding of the extent of soil metal contamination in the Port Colborne area. Therefore, the environmental data on which the health risk study was conducted is sound, and the conclusions are applicable to the results of the 1998 soil investigation.

The health risk study was composed of two parts: 1) a site specific risk assessment, and 2) a review of the epidemiological data for Port Colborne. These studies characteristically rely on extensive modeling and statistical interpolations to arrive at and evaluate potential risk levels. These aspects will not be discussed here. For a more complete understanding of the risk assessment process and how it was applied in Port Colborne it is necessary to read the report [Ref.9].

The MOE site specific risk assessment reviewed Port Colborne environmental contaminant data for water, food (including residential garden produce), soil, and air to evaluate all potential exposure pathways. The estimated maximum total Ni, Cu, and Co exposures for children and adults were compared to US EPA, National Academy of Sciences, and World Health Federation reference doses. These international health reference doses were not exceeded for the maximum exposures calculated for Port Colborne residents. Therefore the MOE report concluded that there are no adverse health effects anticipated to result form exposure to soil metal contamination in Port

Colborne.

The epidemiological component of the study found no evidence to suggest that birth defects or general cancer rates were different from the Ontario population at large. A greater number than expected of lung cancer cases were observed among Port Colborne males for the time period 1979 to 1983. This excess was not related to environmental exposure but may be related to life style and/or occupational exposure.

The report concluded with the following statements. *In conclusion, based on a multi-media assessment of potential risks, no adverse health effects are anticipated to result from exposure to Ni, Cu, or Co, in soils in the Port Colborne area. Furthermore, the review of population health data did not indicate any adverse health effects which may have resulted from environmental exposures.*

11.4 Remediation Measures.

The MOE *Guideline for Use at Contaminated Sites in Ontario* [Ref.8] provides generic soil guidelines for which contaminated soil can be clean-up to such that adverse effects to the natural environment and human health will not occur. For practical or economic reasons contamination may be left on site above the generic criteria. If so, a Site Specific Risk Assessment (SSRA) must be prepared to show that for reasons unique to that particular site the residual contamination does not have the potential to cause an adverse effect to human health or the natural environment. The SSRA approach to site remediation may include engineering principals to physically block exposure pathways. For example, if a contaminated property is being developed for apartment or retail land-use contaminated soil may be covered by pavement or concrete. Another engineering principal may involve chemically or physically manipulating the soil to immobilize the contaminant so that it is not a potential problem for plant uptake. Whenever a contaminated property is cleaned up using the SSRA approach and contamination above the MOE criteria is left in-situ a Record of Site Condition must be prepared that explains what was left behind and why, and registration on title may be required. This process is to insure that subsequent purchasers are informed of the status of the property and they are aware of any maintenance procedures required to maintain the engineering that is intended to prevent the residual contamination from causing an adverse effect.

The soil metal contamination in Port Colborne is not a threat to human health but it is a potential threat to the natural environment, in that the three contaminants of concern are potentially phytotoxic, Ni being the most toxic. The phytotoxicity of Ni is related to how bioavailable it is in soil water, and therefore how readily it can be taken up by plants through their root systems. The potential for phytotoxicity can be reduced by adding a liming agent to the soil to raise the pH. The result is that the Ni forms complexes, usually with Fe and Mn oxides, and becomes significantly less soluble in soil water, and so less available to plants. When soil pH is raised other essential plant nutrients may also become less available, and so fertilizers may be a necessary addition to a liming regime, depending on the type of plants being grown and the amount of lime used. Agricultural liming and fertilizing amends the soil characteristics almost immediately, allowing for rapid remediation of contaminated sites with marginal site disturbance. Depending on the contaminant concentration, the soil physical and chemical characteristics, and the amount of lime and fertilizer required, this remediation process may have to be repeated periodically to maintain the soil pH at

a level that ensures the contaminant remains immobile and the potential for phytotoxicity does not re-occur.

Phytoremediation is a new technology and has promise for significantly reducing the metal content of severely contaminated soil to the point where more traditional remediation strategies become more practical and cost effective. Some species of plants have shown the ability to be hyper-accumulators of metals. These plants, when planted in contaminated soil, absorb substantial amounts of metal from the soil and sequester it in above ground tissue without developing injury symptoms. It would take several growing cycles to substantially reduce the metal concentration of the soil. For some metals, the plants can be ashed and refined and the metals recovered, making the phytoremediation program at least partially cost recoverable. Phytotoremediation has a scale of diminishing returns, in that proportionately less and less can be extracted from the soil with each crop, at which point a liming and fertilizing regime could be implemented to ensure that the residual metal in the soil is rendered unavailable and the potential for phytotoxicity is alleviated.

At sites where the contamination only marginally exceeds remediation criteria and the contamination is concentrated in the surface soil, repeated, deep cultivation may lower metal concentrations in the rooting zone of most plants enough that the soil is no longer potentially phytotoxic. This process is not to be confused with on site mixing, where contaminated soil is stockpiled, clean soil is brought on site, and the two are mixed to a metal concentration that meets the guideline then re-spread over the original area. This practice is restricted to elements that are considered to be essential for plant growth.

12.0 Conclusions

Results of the 1998 Phytotoxicology investigation confirmed that soil to a depth of at least 15 cm in Port Colborne in the vicinity and downwind of the INCO refinery is severely contaminated with Ni, and to a lesser extent with Cu and Co. Based on the soil sampling data and the computer-generated contour maps, MOE Table F soil background *Guidelines* for Ni are exceeded beyond 13 km northeast of INCO over an area greater than 159 km^2, and beyond 4 km in the same direction for Cu (8.9 km^2) and Co (6.1 km^2). Soil Ni concentrations exceed the phytotoxicity-based MOE Table A soil remediation *Guideline* up to 8 km northeast of the refinery over a 19 km^2 area. The Table A criterion for Cu is exceeded over 0.3 km^2, and 1.6 km^2 is contaminated with Co above the Table A criterion. Soil Ni concentrations exceeding Table A are potentially phytotoxic. A health study conducted by the MOE and based on a multi-media assessment of potential risks concluded that no adverse health effects are anticipated to result from exposure to Ni, Cu, or Co in soils in the Port Colborne area.

The soil metal contamination in the Port Colborne area is unquestionably source-oriented, resulting from 66 years of atmospheric deposition from the INCO refinery. These heavy metals are very persistent in soil. Since INCO emissions ceased several years ago, further increases in soil metal concentrations will not occur. Subsequent reductions in soil metal concentrations as a result of natural processes will be extremely gradual. With the cessation of emissions, common landscaping practices at residential properties in the Port Colborne area are affecting local surface soil metal concentrations by creating a patchwork of higher and lower metal levels, which is superimposed on an obvious concentration gradient of Ni, Cu, and Co in soil relative to distance and direction from INCO. Therefore, future periodic surface soil sampling that indicates a reduction in soil metal concentrations would likely be due to disturbances to the sod/surface soil layer rather than actual reductions in the soil contaminant burden. In the absence of INCO emissions and through continued disturbance of surface soils a mosaic of soil metal concentrations will likely become increasingly more prevalent in Port Colborne. However, potentially phytotoxic concentrations of metal contaminated soil would remain just below the layer of cleaner soil on these superficially remediated properties.

One of the objectives of the 1998 Phytotoxicology sampling was to determine if the practice of regularly tilling agricultural fields substantially reduces the soil contaminant burden. If so, the practice of collecting surface soil samples only from undisturbed sites may substantially over-estimate the severity and extent of contamination, particularly in the downwind direction, as this area is predominantly agricultural. Tilling tended to reduce the concentrations in the surface soil layers but increase the concentrations at depth, essentially spreading the contamination throughout the plow layer. The difference between tilled and untilled sites was greatest farthest from INCO, with the metal concentrations at surface being higher in the untilled sites. However, at tilled sites closer to INCO soil metal contamination exceeded Table A *Guidelines* at depths greater than 30 cm. Therefore, tilling may exacerbate remediation efforts as the contamination has been distributed deeper into the soil profile.

Despite a substantial increase in the number of sample sites the complete impact area was not determined, as soil Ni concentrations collected from the farthest downwind sites (>13 km northeast) were still about twice the Table F background value. The sample intensity was adequate

in the city core to accurately estimate the surface soil metal contamination gradient in the most contaminated areas. However, one unusually elevated result at sample site 73 (validated by replicate sampling) may have skewed the computer-generated contours resulting in an over-estimation of the area to the northwest of Port Colborne that exceeds 200 μg/g Ni in soil. Similarly, a few unusually low soil Ni concentrations 4 to 5 km northeast of INCO likely resulted in an under-estimate of the area with soil Ni levels of between 200 and 500 μg/g to the northeast of Port Colborne.

13. 0 References

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Table 1: Station Identification, Sample Depth, Location, Description of Samples - 1998 INCO Port Colborne Soil Investigation

Station No.	Sample Depth (cm)			UTM-E	UTM-N	Distance from stack (km)	Direction (degrees)	Station Description
	0-5	5-10	10-15					
1	X			643427	4749030	372	318	Residential property at corner of Mitchell St. and Kinnear St.
2	X			643280	4748991	463	301	Boulevard at corner of Fares St. and Kinnear St.
3	X	X	X	643238	4748796	442	275	Green space at corner of Rodney St. and Welland St.
4	X	X	X	643465	4749395	675	342	Residential property on north side of Louis St. near Davis St.
5	X			643274	4749505	852	332	Boulevard on west side of Fares St.
6	X			643126	4749687	1083	329	Residential property on east side of Welland St., north of Fraser St.
7	X			643773	4749632	882	6	Boulevard at corner of McRae St. and Colborne St.
8	X			643782	4749880	1130	5	Residential property on east side of McRae St., south of Cross St.
9	X			643923	4749629	908	16	Residential property on south side of Colborne St., west of Athoe St.
10	X			644410	4749933	1387	32	Boulevard on north side of Christmas St.
11	X	X	X	645284	4750064	2072	51	Front yard of Humberstone Public School
12	X	X	X	645700	4752202	3996	30	Right of way , SW corner of Second Concession and Babion Rd.
14	X	X	X	644626	4748351	1030	113	Residential property on Lakeshore Rd near Reuter Rd
15	X			645797	4749011	2134	83	Right of way on east side of Lorraine Rd. - opposite golf course
16	X			646605	4748891	2930	87	Residential property on east side of Weaver Rd.
17	X	X	X	643459	4748645	245	243	Right of way on east side of Lake Rd., near Nickel Beach entrance
19	X	X	X	647294	4754225	6557	33	Residential property on south side of 3rd Concession, west of Miller Rd.
20	X			648270	4748658	4593	91	Scouts Canada property, east side of Pine Crest Rd.
23	X			644006	4754202	5457	3	Right of way - south of 3rd concession, east of Ramey Rd (near canal)
24	X			643496	4748999	304	323	Boulevard at corner of Davis St. and Kinnear St.
25	X			643292	4749724	1,043	338	Boulevard on east side of Fares St., north of Alma St.
26	X			642866	4749201	926	299	Boulevard at SW corner of Kent St. and West St.

Station No.	Sample Depth (cm)			UTM-E	UTM-N	Distance from stack (km)	Direction (degrees)	Station Description
	0-5	5-10	10-15					
27	X			642642	4749505	1279	306	Boulevard at parking lot on Catherine St., opposite Park St. (near railway)
28	X			643649	4748392	364	185	Right of way near parking lot at Nickel Beach Park entrance
29	X			643171	4749928	1,278	337	Boulevard at SE corner of Welland St and Arnaud St.
30	X			640281	4749953	3,602	289	Commercial property on north side of Hwy 3, east of Cement Rd.
31	X			644001	4751184	2,450	8	Right of way at turning circle located at end of Berkeley St.
32	X			643561	4751406	2,654	357	Parkette at corner of Chippawa St. and Berkeley St.
33	X	X	X	643034	4750639	1,991	341	Park on east side of Mellamby Rd. - west of canal bridge to Welland St.
34	X			642560	4749230	1,215	293	Boulevard on north side of Kent St., west of Catherine St.
35	X			642517	4750731	2,292	330	Baseball park at Neff St. and Elm St.
36	X			642417	4749976	1,755	314	Colborne Lions Club Athletic Field (Killaly West and Elm St.)
37	X	X	X	642430	4748868	1,253	275	Lakeview Park, south side of Sugarloaf Rd., west of Elm St.
38	X			641763	4749374	2,013	288	Boulevard on south side of Clarence St., east of Linwood
39	X	X	X	634188	4749795	9,547	276	Residential property on north side of Hwy3, east of Burnaby Rd.
40	X			634342	4747369	9,438	262	Mainfleet Twp. Fire hall #3 - Belleview Rd and Lakeshore Rd.
41	X			637598	4748111	6,114	264	Right of way at corner of Rathfon Rd. and Lakeshore Rd.
42	X			639217	4748573	4,465	268	Residential property at NW corner of Bessie Rd and Lakeshore Rd.
43	X	X	X	645819	4748083	2,244	107	Right of way at SW corner of Lakeshore Rd. E and Lorraine.
44	X			649883	4748876	6,206	89	Residential property on Silver Bay Rd., SE corner of Fire line 7
45	X	X	X	653188	4748275	9,522	93	Right of way at NE corner of Pleasant Beach Rd. and Niagara Rd. #1
46	X			653808	4750348	10,254	81	Right of way at NW corner of Hwy 3 and Ft. Erie Town line
47	X			650656	4750224	7,131	78	Residential property at SW corner of Hwy 3 and Wildewood
48	X			649764	4750149	6,244	77	Church of the Lutheran Hour - SW corner of Hwy 3 and Silver Bay Rd.
49	X	X	X	648287	4750322	4,868	71	Residential property on White Rd. where Killaly Rd. meets Hwy 3
50	X	X	X	646601	4750038	3,192	66	Residential property on west side of Weaver Rd., north of Killaly Rd. East

Station No.	Sample Depth (cm)			UTM-E	UTM-N	Distance from stack (km)	Direction (degrees)	Station Description
	0-5	5-10	10-15					
51	X	X	X	644999	4750220	1,973	42	Residential property on south side of Killaly Rd., east of Snider Rd.
52	X			640881	4749990	3,058	294	Commercial property , south side of Niagara #5 where Hwy 3 turns north.
53	X	X	X	639319	4749978	4,527	286	Commercial property on north side of Hwy 3, east of Erie Peat Rd.
54	X			637559	4749894	6,224	281	Right of way on SW corner of Hwy 3 and Rathfon Rd.
55	X	X	X	635823	4749866	7,933	278	Residential property on NW corner of Dilts Rd. and Hwy 3
56	X			634356	4751835	9,818	288	Residential property on north side of Barrick Rd., east of Side Road #16.
58	X			639063	4751372	5305	300	Residential property at north end of Erie Peat Rd. (at entrance to peat plant)
59	X			640733	4752140	4,487	319	Residential property on north side of Barrick Rd, east of Minor Rd.
60	X			642352	4752071	3,571	338	Residential property on south side of Barrick Rd., west of Elm St.
61	X			644370	4752263	3,576	11	Residential property, at Chippawa Rd. and Second Concession Line.
62	X	X	X	648282	4751947	5,602	55	Residential property on east side of White Rd. south of 2nd Concession Line
63	X	X	X	647717	4752174	5,292	50	Cemetery on north side of Second Concession Line, east of Lorraine Rd.
64	X			649022	4752206	6,361	57	Golf course property at corner of Sherk Rd. and Second Concession Line.
65	X			649923	4752004	7,040	63	Residential property on SE corner Brookfield and Second Concession.
66	X			651170	4752315	8,295	65	Residential property on north side of Second Concession at Clarke Rd.
67	X			652499	4752326	9,516	68	Residential property on NE corner of Wilhelm Rd and Second Concession
68	X			654432	4752110	11,295	73	Residential property on SW corner of Burtie St and Burger Rd.
69	X			654265	4754213	11,911	63	Residential property on east side of Burger Rd. (south of gas pipeline)
70	X			652110	4755419	10,747	52	Residential property on north side of Lever Rd. at Neff Rd.
71	X			648915	4754245	7,587	44	Residential property, south side of 3rd Concession Line, west of Sherk Rd.
72	X	X	X	645744	4754275	5,894	21	Residential property, north side of 3rd Concession Line, east of Babion Rd.
73	X			642368	4753517	4,939	345	Commercial property near landfill entrance, Elm St. and Invertose Dr.
74	X			640213	4754689	6,872	330	Residential property on west side of Town Line Rd (near end of road)
75	X			638947	4754676	7,579	321	Residential property near end of Concession Road No. 4

Station No.	Sample Depth (cm)			UTM-E	UTM-N	Distance from stack (km)	Direction (degrees)	Station Description
	0-5	5-10	10-15					
76	X			636584	4753687	8,640	305	Residential property on east side of Wilson Rd #10, south of Feeder Rd.
77	X			633929	4753457	10,824	296	Residential property on west side of Sider Rd #16, south of Feeder Rd.
78	X			634744	4755792	11,373	308	Right of way on SE corner of Forks Rd. and Overholt Rd.
79	X			636452	4755980	10,218	315	Right of way on NE corner of Forks Rd. and Deeks Rd.
80	X			638556	4755942	8,825	325	Residential property on south side of Forks Rd., east of Feeder Rd. E.
81	X			641578	4756262	7,795	344	Residential property on north side of Forks Rd., west of Hwy 58
82	X			644972	4756247	7,603	10	Residential property on south side of Forks Rd., east of Snider Rd.
83	X			646536	4756318	8,085	21	Residential property on NE corner of Yager Rd. and Forks Rd.
84	X	X	X	648149	4756260	8,736	31	Commercial property on SE corner of White Rd. and Forks Rd.
85	X			649995	4756392	9,911	40	Residential property on NW corner of Brookfield Rd and Forks Rd.
86	X	X	X	652000	4756445	11,331	47	Residential property on SW corner of Forks Rd. and Koabel Rd.
87	X			654352	4756192	13,009	55	Residential property on east side of Burger Rd. (near Forkes Rd.)
88	X			653093	4758112	13,274	45	Right of way at Durbiat Rd. and Netherby Rd.
89	X	X	X	650298	4758043	11,406	35	Residential property on south side of Netherby Rd., east of Brookfield Rd.
90	X			647280	4757954	9,879	21	Residential property on south side of Netherby Rd., east of Strawn Rd.
91	X			645489	4757964	9,385	11	Residential property on north side of Netherby Rd., west of Rusholm Rd.
150	X			644308	4750382	1,745	21	Residential property on north side of Killaly St., east of Elizabeth St.
151	X			644452	4750975	2,351	19	Woodlot located north of Killaly St., east of Elizabeth St.
159	X			647414	4755448	7,665	29	Residential property, east side of Miller Rd. between 3rd Conc. and Forkes

Table 2: Station Identification, Location, and Description of Samples for Tilled vs. Untilled Soil Profiles for Farm Properties along a NE Transect from INCO (soil sampled at 0-5, 5-10, 10-15, 15-20, 20-25, 25-30 cm depths)

Station	UTM-E	UTM-N	Distance from Stack (km)	Direction (degrees)	Description
157	644311	4750385	1749	21	Rural property on north side of Killaly St., east of Elizabeth St. - front yard of residence
158	644366	4750391	1,775	23	Rural property on north side of Killaly St., east of Elizabeth St. - tilled field near residence
160	647402	4755489	7,695	29	Rural property, east side of Miller Rd. between 3rd Conc. and Forkes- front yard of residence
161	647438	4755353	7,594	30	Rural property, east side of Miller Rd. between 3rd Conc. and Forkes- tilled field near residence
162	645725	4752876	4,601	26	Rural property at corner of Babion Rd. and Chippiwa Rd.- right of way
163	645730	4752876	4,604	26	Rural property at corner of Babion Rd. and Chippiwa Rd. - tilled field adjacent to right of way
164	650310	4757978	11,360	36	Rural property on south side of Brookfield Rd at Town line - backyard of residence
165	650310	4757973	11,356	36	Rural property on south side of Brookfield Rd. at Town line - tilled field near residence backyard

Table 3: Relationship Between Nickel, Cobalt, and Copper in the Soil Profile and Surface Nickel Concentrations in Soil Collected from the port Colborne Area, 1998.

Area*	Soil Depth	Nickel	Cobalt	Copper
Surface nickel concentration exceeds Table A Guideline	0-5 cm	1087 (305 - 2750)	24 (13 - 52)	114 (46 - 275)
	5-10 cm	913 (315 - 2750)	19 (7 - 47)	101 (46 - 270)
	10-15 cm	699 (52 - 3200)	17 (2 - 53)	80 (12 - 305)
Surface nickel concentration does not exceed Table A Guideline	0-5 cm	78 (18 - 160)	9 (4 - 15)	27 (15 -38)
	5-10 cm	102 (20 - 450)	10 (5 - 17)	29 (14 - 63)
	10-15 cm	106 (20 - 160)	10 (5 -15)	27 (12 - 38)

*Areas determined from contour mapping (Surfer-Arcview) in which nickel concentration in surface soil (0-5 cm) falls above or below MOE Table A guideline for nickel = 200 μg/g (medium/fine textured soils)
Range shown in brackets

Table 4: Effect of Tillage on the Distribution of Nickel, Copper, and Cobalt in Soil at Four Sites in the Port Colborne Area (Tilled vs Untilled).

Farm*	Disturbance**	Depth					
		0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
Nickel							
A	Not Tilled	**1100**	**1700**	**990**	**830**	**460**	***110***
	Tilled	**1100**	**1100**	**1100**	**1100**	**840**	***138***
B	Not Tilled	***110***	***110***	***115***	***98***	***56***	36
	Tilled	***105***	***115***	***105***	***84***	***54***	28
C	Not Tilled	***140***	***145***	***109***	***58***	***44***	38
	Tilled	***82***	***70***	***54***	30	24	29
D	Not Tilled	***51***	***52***	***44***	43	28	39
	Tilled	42	40	39	35	33	36
Cobalt							
A	Not Tilled	***27.0***	***33.0***	19.0	18.0	11.0	7.3
	Tilled	***22.5***	***23.5***	***24.0***	***23.5***	21.0	16.0
B	Not Tilled	6.1	6.0	6.3	6.3	5.6	6.0
	Tilled	6.4	6.9	6.3	6.6	8.1	9.0
C	Not Tilled	12.5	13.5	13.5	15.0	16.5	18.5
	Tilled	9.3	8.0	8.3	8.5	9.8	12.0
D	Not Tilled	6.6	7.6	8.3	9.8	13.0	17.0
	Tilled	9.7	9.5	11.0	12.5	16.5	16.0
Copper							
A	Not Tilled	***140***	***200***	***130***	***96***	60	27
	Tilled	***130***	***125***	***125***	***130***	***103***	29
B	Not Tilled	25	26	25	23	16	16
	Tilled	24	25	24	22	24	26
C	Not Tilled	39	39	31	23	21	22
	Tilled	29	26	22	14	14	19
D	Not Tilled	27	28	23	19	17	22
	Tilled	17	17	18	18	21	25

* Farms A through D are located at increasing distances from INCO stack
** Tilled = fields with conventional agricultural tillage, Not tilled = lawn areas with no known recent disturbance.
All data represent mean of duplicate samples, air dry weight.
Values shown in bold indicate concentrations exceeding the corresponding Table F Guideline; Shaded cells indicate values greater than corresponding Table A Guideline.

Table 5: Comparison of Nickel Concentrations in Soil Over Time from Common Collection Sites - Port Colborne, 1972-1998

Station	0-5 cm				5-10 cm			
	1974	1980	1991	1998	1974	1980	1991	1998
2292002		**4350**	**4700**	**1400**		**7400**		
2292004	**803**	**3500**	**3950**	**2050**	**823**	**3200**	*61*	*47*
2292005	**393**	**710**	**805**	**585**		**520**		
2292007		**3300**	**4750**	**210**		**5650**		
2292008	**2080**		**960**	**595**				
2292009	**23800**	**8250**	**6400**	**2250**	**6750**	**3130**		
2292010	**16300**	**650**	**465**	21*	**3750**	**305**		
2292011	**3380**		**1030**	**980**	**415**		**1150**	
2292012	**800**	*140*	**380**	*78*	**800**	**630**	**340**	
2292013	**245**				**240**			
2292014	**433**		**6000**	**585**	**440**		**1275**	**530**
2292015	**1500**		**500**	**1400**	**1050**			
2292016	*200*		**255**	**310**	**215**			
2292018		**860**	**345**			**680**		
2292019		**245**		*104*		*178*		*110*
2292024		**5100**	**3400**	**5050**		**1780**		

Values shown represent concentrations reported for individual samples 1974-1982, means for duplicate samples collected in 1991 and 1998, all reported as $\mu g/g$ air dry weight.
Values shown in bold exceed Table F Guideline of 43 $\mu g/g$ Ni for non-agricultural soils,
Shaded cells exceed Table A Guidelines of 200 $\mu g/g$ Ni for fine-textured, residential soils (See text).
* Soil is likely recently imported for landscaping purposes

Table 6: Comparison of Cobalt Concentrations in Soil Over Time from Common Collection Sites - Port Colborne, 1972-1998

Station	0-5 cm				5-10 cm			
	1974	1980	1991	1998	1974	1980	1991	1998
2292002		**100**		**34**		**130**		
2292004	**128**	**58**		6	**108**	**55**	*33*	6
2292005	*38*	*23*	*25*	20		*23*		
2292007		**75**	**150**	9*		**90**		
2292008	*33*		*26*	19				
2292009	**518**	**240**	**65**	**56**	**108**	*45*		
2292010	**150**	*35*	19	5	**65**	*23*		
2292011	**73**		*32*	16	*43*		20	18
2292012	*38*	15	13	19	*38*	*25*	12	15
2292013	18				13			
2292014	**83**		**88**	7	**73**		*25*	2
2292015	*45*		16	*43*	*45*			
2292016	*35*		8	11	*45*			
2292018		*23*	15			15		
2292019		15	15	20		15		17
2292024		**128**	12	**105**		*35*		

Values shown represent concentrations reported for individual samples 1972-1982, means for duplicate samples collected in 1991 and 1998, all reported as μg/g air dry weight.
Values shown in bold exceed Table F Guideline of 21 μg/g Co for non-agricultural soils,
Shaded cells exceed Table A Guidelines of 50 μg/g Co for fine-textured, residential soils (See text).
* Soil is likely recently imported for landscaping purposes

Table 7: Comparison of Copper Concentrations in Soil from Common Collection Sites - Port Colborne area, 1972-1998

Station	0-5 cm				5-10 cm			
	1974	1980	1991	1998	1974	1980	1991	1998
2292002		**360**	**520**	***165***		**560**		
2292004	***280***	**325**	**430**	***205***	**345**	**310**	26	***270***
2292005	75	***130***	***140***	***115***		***115***		
2292007		**375**	**625**	45*		**465**		
2292008				79		***98***		
2292009	**1230**	**1180**	**820**	***240***	**325**	**335**		
2292010	**400**	***135***	***98***	17	***263***	75		
2292011	***188***		***175***	***125***	73		***165***	
2292012	53	40	56	30	70	***100***	54	
2292013	23				23			
2292014	40		**770**	69	40		***220***	
2292015	***88***		***99***	***165***	68			
2292016	20		49	51	23			
2292018		***115***	***98***			***95***		
2292019		55	33	22		50		23
2292024		**330**	***285***	**350**		***185***		

Values shown represent concentrations reported for individual samples 1972-1982, means for duplicate samples collected in 1991 and 1998, all reported as $\mu g/g$ air dry weight.
Values shown in bold exceed Table F Guideline of 85 $\mu g/g$ Cu for non-agricultural soils,
Shaded cells exceed Table A Guidelines of 300 $\mu g/g$ Cu for fine-textured, residential soils (See text).
* Soil is likely recently imported for landscaping purposes

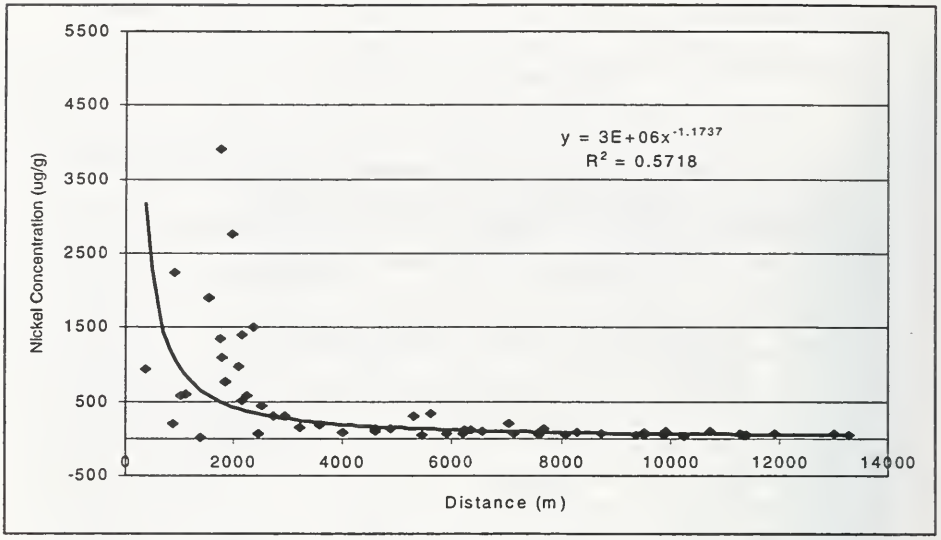


Figure 1: Distribution of Nickel in Surface Soil (0-5 cm) with Distance from the INCO Stack in the NE Quadrant, 1998.

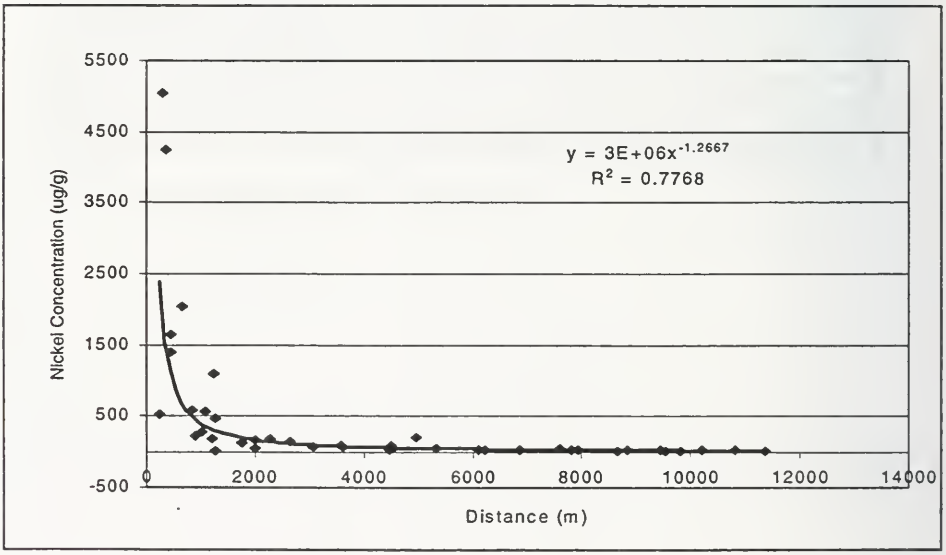


Figure 2: Distribution of Nickel in Surface Soil (0-5 cm) with Distance from the INCO Stack in the NW Quadrant, 1998.

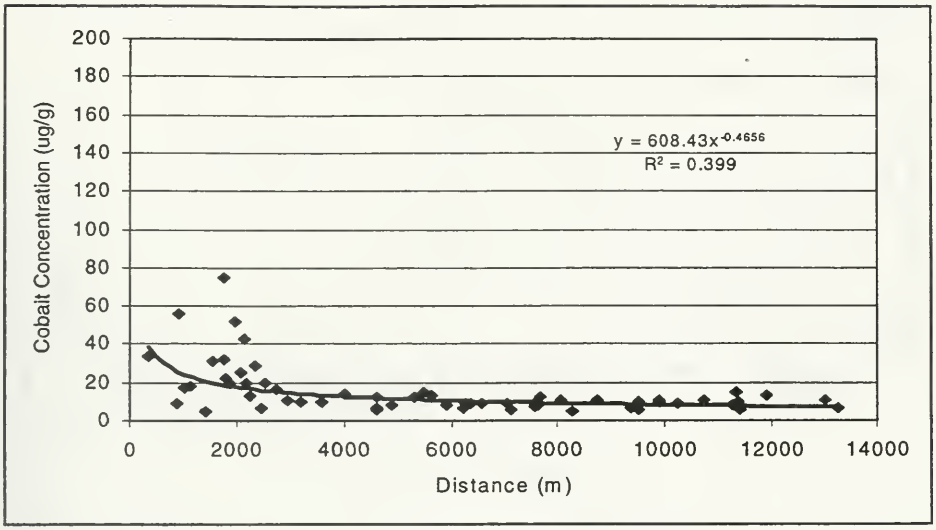


Figure 3: Distribution of Cobalt in Surface Soil (0-5 cm) with Distance from the INCO Stack in the NE Quadrant, 1998.

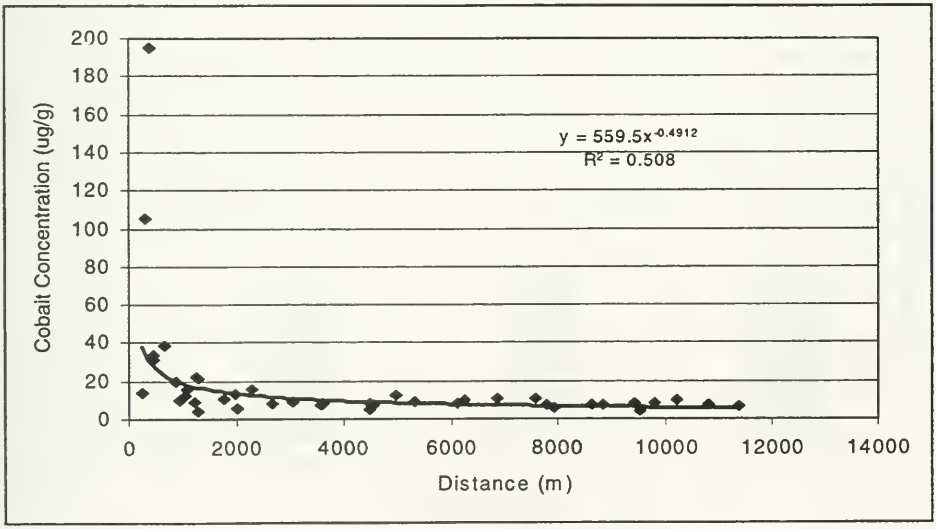


Figure 4: Distribution of Cobalt in Surface Soil (0-5 cm) with Distance from the INCO Stack in the NW Quadrant, 1998.

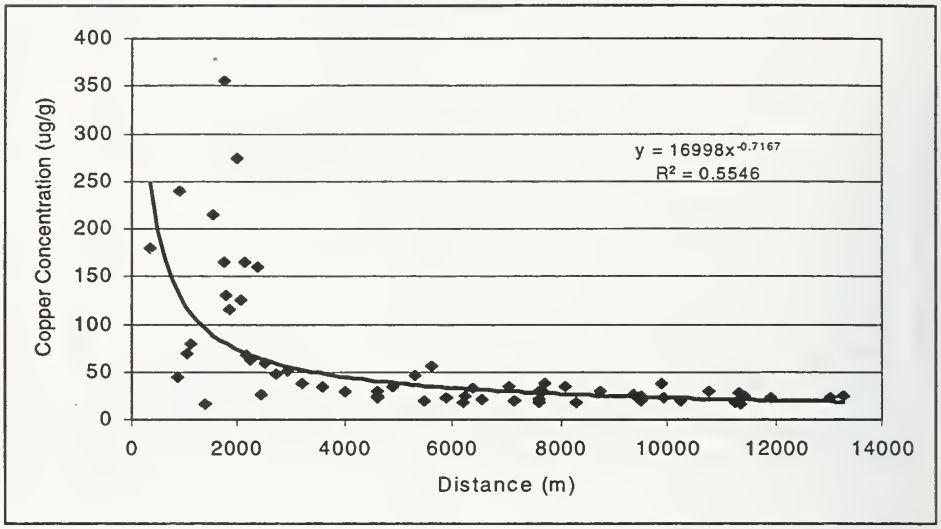


Figure 5: Distribution of Copper in Surface Soil (0-5 cm) with Distance from the INCO Stack in the NE Quadrant, 1998.

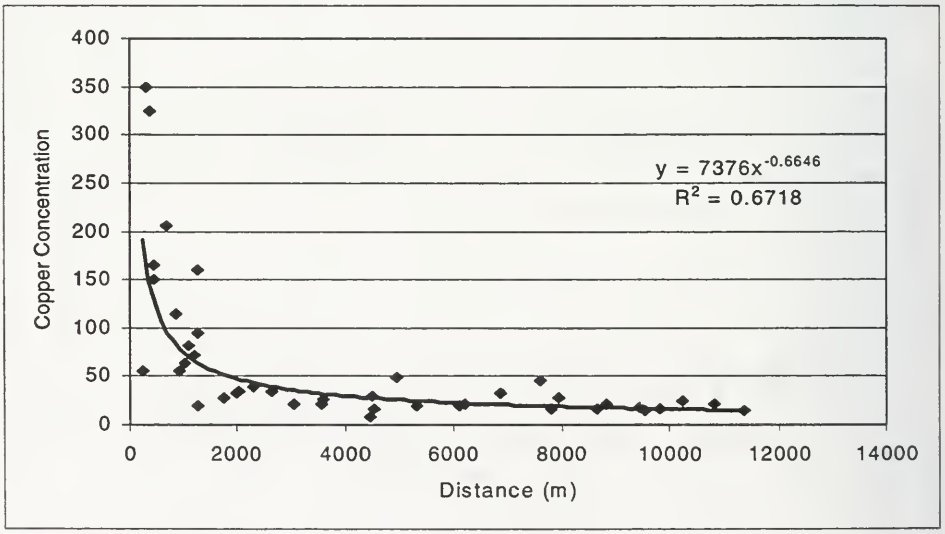


Figure 6: Distribution of Copper in Surface Soil (0-5 cm) with Distance from the INCO Stack in the NW Quadrant, 1998.

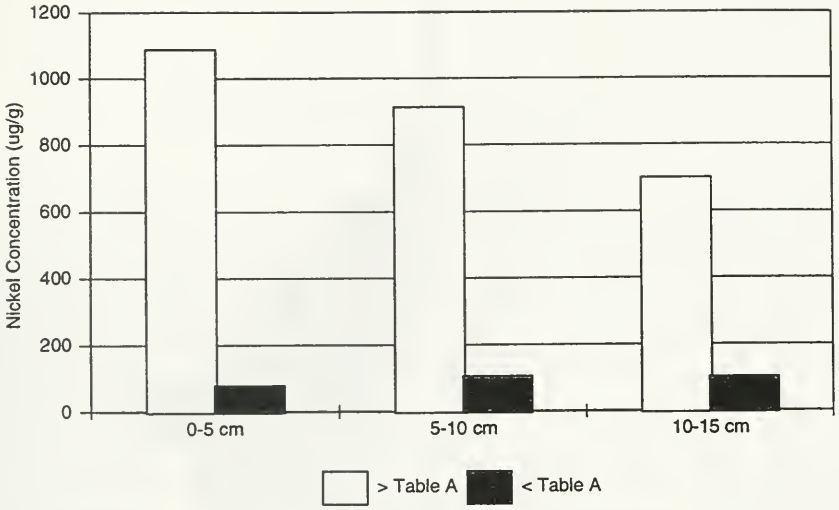


Figure 7: Relationship Between Soil Nickel Concentrations and Sampling Depth in Areas of Port Colborne Where the Effects -Based Soil Guideline (Table A) is Exceeded vs Areas Where it is Not Exceeded.

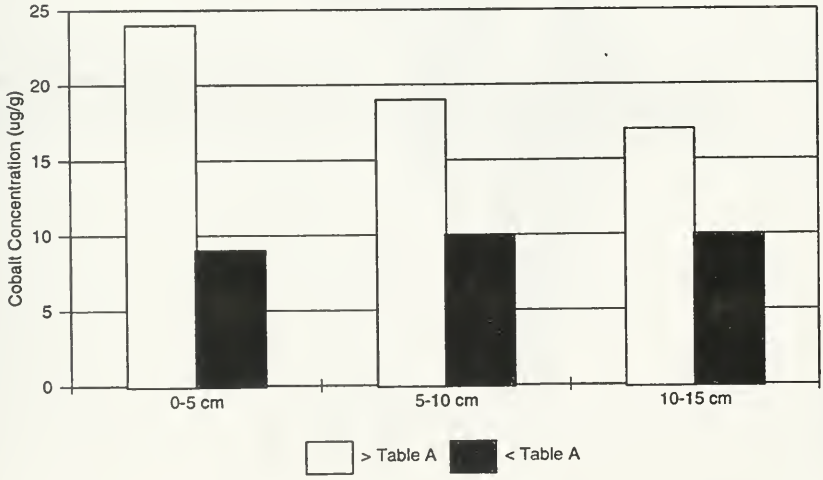


Figure 8: Relationship Between Soil Cobalt Concentrations and Sampling Depth in Areas of Port Colborne Where the Effects -Based Soil Guideline (Table A) is Exceeded vs Areas Where it is Not Exceeded.

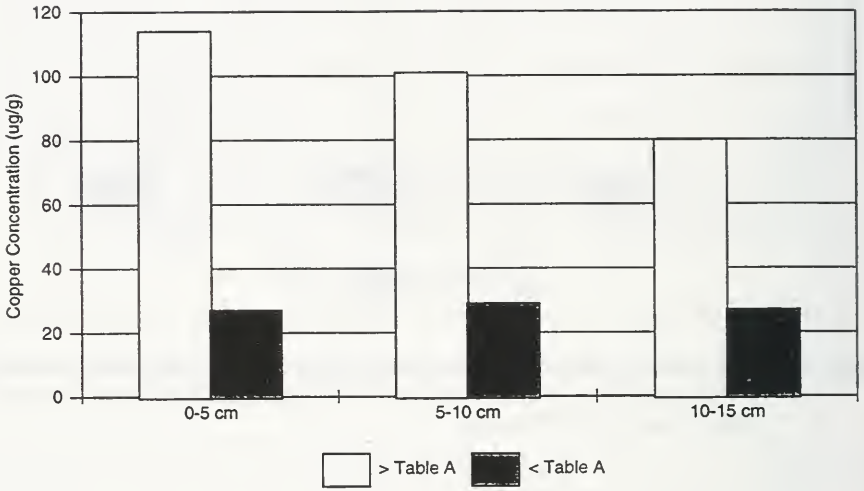


Figure 9: Relationship Between Soil Copper Concentrations and Sampling Depth in Areas of Port Colborne Where the Effects -Based Soil Guideline (Table A) is Exceeded vs Areas Where it is Not Exceeded.

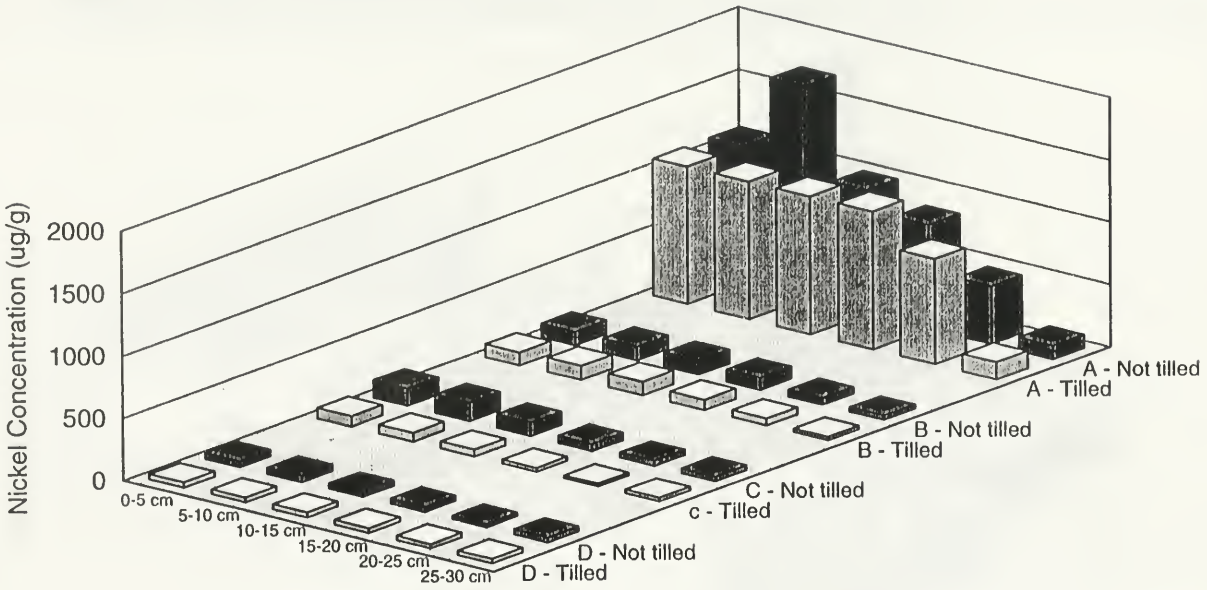


Figure 10: Comparison of Nickel Concentrations in Soil at Tilled Agricultural Sites vs Untilled Sites at Four Farms Along a Transect to the NE of INCO, Port Colborne, 1998. Farm A is Closest, and D most distant.

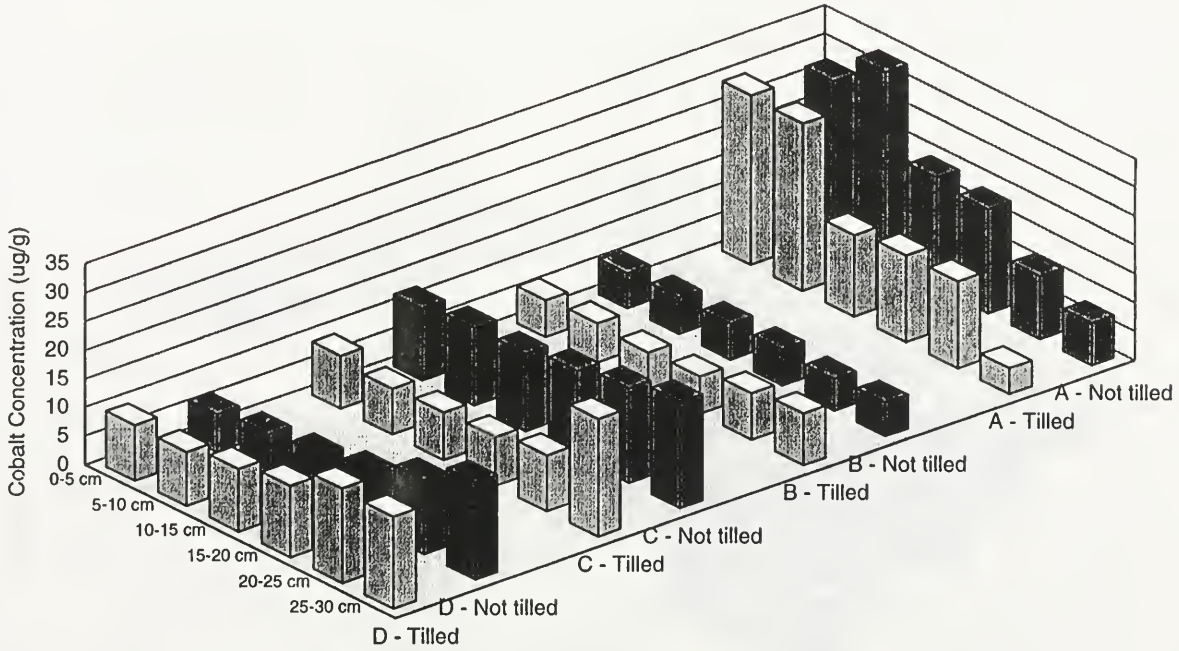


Figure 11: Comparison of Cobalt Concentrations in Soil at Tilled Agricultural Sites vs Untilled Sites at Four Farms Along a Transect to the NE of INCO, Port Colborne, 1998. Farm A is Closest, and D most distant.

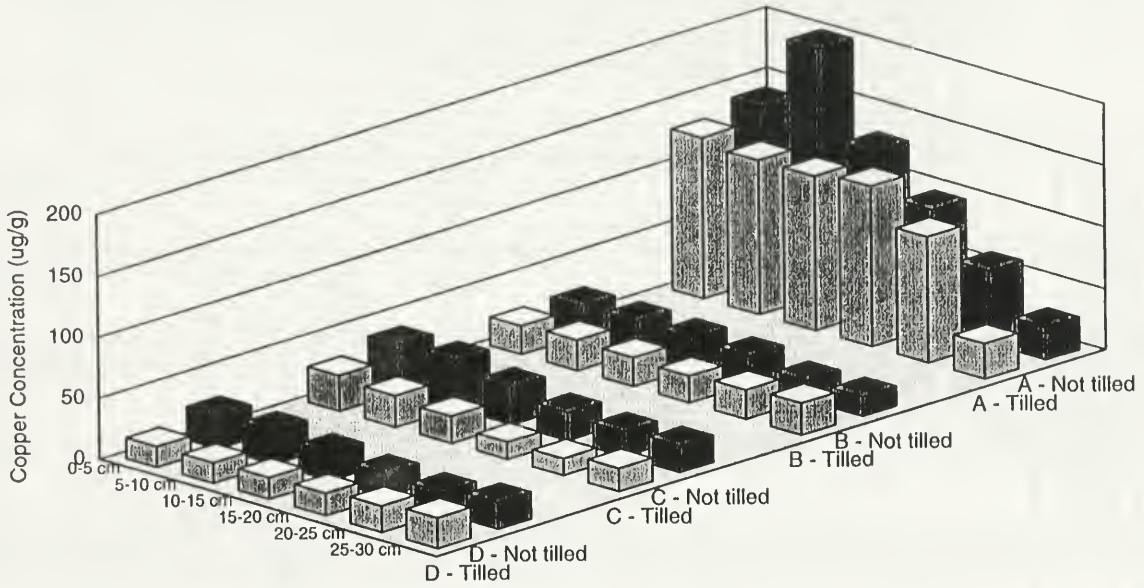


Figure 12: Comparison of Copper Concentrations in Soil at Tilled Agricultural Sites vs Untilled Sites at Four Farms Along a Transect to the NE of INCO, Port Colborne, 1998. Farm A is Closest, and D most distant.

Appendix A-1: Concentrations of nickel in soil collected in the Port Colborne area, 1998.

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
1	Residential	372	318	4250					
2	Boulevard	463	301	1400					
3	Residential	442	275	1650	1550	1650			
4	Residential	675	342	2050	2750	3200			
5	Boulevard	852	332	585					
6	Residential	1083	329	560					
7	Boulevard	882	6	210					
8	Residential	1130	5	595					
9	Residential	908	16	2250					
10	Boulevard	1387	32	21					
11	School yard	2072	51	980	995	980			
12	Right-of-way	3996	30	*78*	*58*	*59*			
14	Residential	1030	113	585	530	*180*			
15	Right-of-way	2134	83	1400					
16	Residential	2930	87	310					
17	Right-of-way	245	243	520	765	270			
19	Right-of-way	6557	33	*104*	*110*	*98*			
20	Lawn	4593	91	*130*					
23	Right-of-way	5457	3	*50*					
24	Boulevard	304	323	5050					
25	Boulevard	1043	338	270					
26	Boulevard	926	299	215					
27	Boulevard	1279	306	15					
28	Right-of-way	364	185	940					
29	Boulevard	1278	337	470					
30	Lawn	3602	289	*65*					
31	Right-of-way	2450	8	*66*					
32	Park	2654	357	*155*					
33	Park	1991	341	*160*	450	605			
34	Boulevard	1215	293	*175*					
35	Park	2292	330	*185*					
36	Park	1755	314	*125*					
37	Park	1253	275	1100	410	*52*			
38	Boulevard	2013	288	*58*					
39	Residential	9547	276	18	20	20			
40	Lawn	9438	262	30					
41	Right-of-way	6114	264	37					
42	Residential	4465	268	23					
43	Right-of-way	2244	107	580	460	*119*			
44	Residential	6206	89	*74*					
45	Right-of-way	9522	93	*46*	*46*	39			
46	Right-of-way	10254	81	31					
47	Residential	7131	78	*63*					
48	Lawn	6244	77	*115*					
49	Residential	4868	71	*130*	*165*	*140*			
50	Residential	3192	66	*145*	*150*	*120*			
51	Residential	1973	42	2750	950	580			
52	Lawn	3058	294	*74*					
53	Lawn	4527	286	*54*	*53*	41			
54	Right-of-way	6224	281	38					
55	Residential	7933	278	41	40	27			
56	Residential	9818	288	20					

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
58	Residential	5305	300	***48***					
59	Residential	4487	319	***89***					
60	Residential	3571	338	***92***					
61	Residential	3576	11	***190***					
62	Residential	5602	55	**345**	**405**	**445**			
63	Cemetery	5292	50	**305**	**315**	***160***			
64	Lawn	6361	57	***115***					
65	Residential	7040	63	***195***					
66	Residential	8295	65	***77***					
67	Residential	9516	68	***78***					
68	Residential	11265	73	***68***					
69	Residential	11911	63	***65***					
70	Residential	10747	52	***97***					
71	Residential	7587	44	***83***					
72	Residential	5894	21	***73***	***69***	***71***			
73	Lawn	4939	345	***195***					
74	Residential	6872	330	38					
75	Residential	7579	321	***44***					
76	Residential	8640	305	20					
77	Residential	10824	296	24					
78	Right-of-way	11373	308	17					
79	Right-of-way	10218	315	24					
80	Residential	8825	325	33					
81	Residential	7795	344	29					
82	Residential	7603	10	***55***					
83	Residential	8085	21	***55***					
84	Lawn	8736	31	***69***	***74***	***62***			
85	Residential	9911	40	***96***					
86	Residential	11331	47	***52***	***50***	***55***			
87	Residential	13009	55	***69***					
88	Right-of-way	13274	45	***48***					
89	Residential	11406	35	42	***45***	***45***			
90	Residential	9879	21	42					
91	Residential	9385	11	***49***					
150	Residential	1745	21	**3900**					
151	Woodlot	1749	21	**1500**					
**157	Residential	1749	21	**1100**	**1700**	**990**	**830**	**460**	***110***
158	Tilled	1775	23	**1100**	**1100**	**1100**	**1100**	**840**	***138***
159	Residential	7655	29	***103***					
160	Untilled	7695	26	***140***	***145***	***109***	***58***	***44***	38
161	Tilled	7594	30	***82***	***70***	***54***	30	24	29
162	Right-of-way	4601	26	***110***	***110***	***115***	***98***	***56***	36
163	Tilled	4604	26	***105***	***115***	***105***	84	***54***	28
164	Residential	11360	36	***51***	***52***	***44***	43	28	39
165	Tilled	11356	36	42	40	39	35	33	36

*Distance (meters) and direction (degrees) from INCO stack.
**Single samples only at Site 157 (See text).
Data are average of duplicate samples, μg/g air-dry weight.
Bold italic data exceed Table F *Guideline* for nickel in non-agricultural soils (43 μg/g Ni).
Shaded data exceed Table A *Guideline* for nickel in medium/fine-textured residential/parkland soil (200 μg/g Ni).

Appendix A-2: Concentrations of cobalt in soil collected in the Port Colborne area, 1998.

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
1	Residential	372	318	195.0					
2	Boulevard	463	301	*33.5*					
3	Residential	442	275	*31.0*	*28.0*	29.5			
4	Residential	675	342	*39.0*	*46.5*	52.5			
5	Boulevard	852	332	19.5					
6	Residential	1083	329	16.0					
7	Boulevard	882	6	9.4					
8	Residential	1130	5	18.5					
9	Residential	908	16	56.0					
10	Boulevard	1387	32	5.1					
11	School yard	2072	51	*25.5*	*29.5*	*29.0*			
12	Right-of-way	3996	30	14.0	15.0	15.0			
14	Residential	1030	113	17.5	10.0	3.8			
15	Right-of-way	2134	83	*42.5*					
16	Residential	2930	87	11.0					
17	Right-of-way	245	243	14.0	13.4	7.7			
19	Right-of-way	6557	33	9.1	9.2	9.1			
20	Lawn	4593	91	12.0					
23	Right-of-way	5457	3	14.5					
24	Boulevard	304	323	105.0					
25	Boulevard	1043	338	12.5					
26	Boulevard	926	299	9.5					
27	Boulevard	1279	306	4.3					
28	Right-of-way	364	185	*33.5*					
29	Boulevard	1278	337	21.0					
30	Lawn	3602	289	8.2					
31	Right-of-way	2450	8	6.9					
32	Park	2654	357	8.6					
33	Park	1991	341	13.0	15.5	17.5			
34	Boulevard	1215	293	9.4					
35	Park	2292	330	15.5					
36	Park	1755	314	10.5					
37	Park	1253	275	*22.5*	7.2	2.4			
38	Boulevard	2013	288	5.6					
39	Residential	9547	276	4.5	4.6	4.9			
40	Lawn	9438	262	8.1					
41	Right-of-way	6114	264	8.0					
42	Residential	4465	268	4.9					
43	Right-of-way	2244	107	13.0	10.5	4.0			
44	Residential	6206	89	6.3					
45	Right-of-way	9522	93	5.9	6.2	6.4			
46	Right-of-way	10254	81	9.5					
47	Residential	7131	78	6.0					
48	Lawn	6244	77	8.9					
49	Residential	4868	71	8.5	9.2	9.1			
50	Residential	3192	66	9.7	10.5	10.5			
51	Residential	1973	42	51.5	18.5	15.0			
52	Lawn	3058	294	9.0					
53	Lawn	4527	286	7.5	8.2	8.5			
54	Right-of-way	6224	281	9.7					
55	Residential	7933	278	6.1	5.8	5.9			
56	Residential	9818	288	8.2					
58	Residential	5305	300	8.9					

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
59	Residential	4487	319	8.5					
60	Residential	3571	338	7.4					
61	Residential	3576	11	9.6					
62	Residential	5602	55	13.0	14.0	14.0			
63	Cemetery	5292	50	12.5	11.5	9.1			
64	Lawn	6361	57	9.1					
65	Residential	7040	63	9.3					
66	Residential	8295	65	5.3					
67	Residential	9516	68	10.0					
68	Residential	11265	73	8.5					
69	Residential	11911	63	13.5					
70	Residential	10747	52	11.0					
71	Residential	7587	44	7.0					
72	Residential	5894	21	8.1	9.7	10.0			
73	Lawn	4939	345	12.5					
74	Residential	6872	330	10.4					
75	Residential	7579	321	11.0					
76	Residential	8640	305	7.3					
77	Residential	10824	296	7.3					
78	Right-of-way	11373	308	6.3					
79	Right-of-way	10218	315	9.7					
80	Residential	8825	325	7.4					
81	Residential	7795	344	7.4					
82	Residential	7603	10	9.6					
83	Residential	8085	21	10.5					
84	Lawn	8736	31	11.0	12.5	6.0			
85	Residential	9911	40	10.5					
86	Residential	11331	47	15.0	16.5	14.5			
87	Residential	13009	55	10.5					
88	Right-of-way	13274	45	6.7					
89	Residential	11406	35	6.2	6.5	6.7			
90	Residential	9879	21	10.0					
91	Residential	9385	11	6.4					
150	Residential	1745	21	74.5					
151	Woodlot	2351	19	***29.0***					
**157	Residential	1749	21	***27.0***	***33.0***	19.0	18.0	11.0	7.3
158	Tilled	1775	23	***22.5***	***23.5***	***24.0***	***23.5***	21.0	16.0
159	Residential	7665	29	8.1					
160	Untilled	7695	29	12.5	13.5	13.5	15.0	16.5	18.5
161	Tilled	7594	30	9.3	8.0	8.3	8.5	9.8	12.0
162	Right-of-way	4601	26	6.1	6.0	6.3	6.3	5.6	6.0
163	Tilled	4604	26	6.4	6.9	6.3	6.6	8.1	9.0
164	Residential	11360	36	6.6	7.6	8.3	9.8	13.0	17.0
165	Tilled	11356	36	9.7	9.5	11.0	12.5	16.5	16.0

*Distance (meters) and direction (degrees) from INCO stack.
**Single sample only at Site 157 (See text).
Data are average of duplicate samples, μg/g air-dry weight.
Bold italic data exceed Table F *Guideline* for cobalt in non-agricultural soils (21 μg/g Co).
Shaded data exceed Table A *Guideline* for cobalt in medium/fine-textured residential/parkland soil (50 μg/g Co).

Appendix A-3: Concentrations of copper in soil collected in the Port Colborne area, 1998.

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
1	Residential	372	318	325					
2	Boulevard	463	301	*165*					
3	Residential	442	275	*150*	*150*	*160*			
4	Residential	675	342	*205*	*270*	305			
5	Boulevard	852	332	*115*					
6	Residential	1083	329	81					
7	Boulevard	882	6	45					
8	Residential	1130	5	79					
9	Residential	908	16	*240*					
10	Boulevard	1387	32	17					
11	School yard	2072	51	*125*	*125*	*125*			
12	Right-of-way	3996	30	30	29	29			
14	Residential	1030	113	69	53	18			
15	Right-of-way	2134	83	*165*					
16	Residential	2930	87	51					
17	Right-of-way	245	243	56	75	31			
19	Right-of-way	6557	33	22	23	21			
20	Lawn	4593	91	29					
23	Right-of-way	5457	3	20					
24	Boulevard	304	323	350					
25	Boulevard	1043	338	63					
26	Boulevard	926	299	55					
27	Boulevard	1279	306	19					
28	Right-of-way	364	185	*180*					
29	Boulevard	1278	337	*160*					
30	Lawn	3602	289	26					
31	Right-of-way	2450	8	27					
32	Park	2654	357	34					
33	Park	1991	341	32	63	80			
34	Boulevard	1215	293	72					
35	Park	2292	330	39					
36	Park	1755	314	28					
37	Park	1253	275	*96*	46	12			
38	Boulevard	2013	288	35					
39	Residential	9547	276	15	14	13			
40	Lawn	9438	262	18					
41	Right-of-way	6114	264	19					
42	Residential	4465	268	9					
43	Right-of-way	2244	107	63	54	16			
44	Residential	6206	89	18					
45	Right-of-way	9522	93	26	26	26			
46	Right-of-way	10254	81	21					
47	Residential	7131	78	20					
48	Lawn	6244	77	25					
49	Residential	4868	71	34	38	35			
50	Residential	3192	66	38	38	32			
51	Residential	1973	42	*275*	*130*	*87*			
52	Lawn	3058	294	22					
53	Lawn	4527	286	17	14	12			
54	Right-of-way	6224	281	22					
55	Residential	7933	278	28	27	21			
56	Residential	9818	288	17					

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
58	Residential	5305	300	20					
**59	Residential	4487	319	29					
60	Residential	3571	338	21					
61	Residential	3576	11	35					
62	Residential	5602	55	56	63	68			
63	Cemetery	5292	50	46	48	33			
64	Lawn	6361	57	33					
65	Residential	7040	63	35					
66	Residential	8295	65	19					
67	Residential	9516	68	20					
68	Residential	11265	73	19					
69	Residential	11911	63	23					
70	Residential	10747	52	30					
71	Residential	7587	44	19					
72	Residential	5894	21	23	22	22			
73	Lawn	4939	345	50					
74	Residential	6872	330	33					
75	Residential	7579	321	47					
76	Residential	8640	305	17					
77	Residential	10824	296	22					
78	Right-of-way	11373	308	15					
79	Right-of-way	10218	315	25					
80	Residential	8825	325	21					
81	Residential	7795	344	17					
82	Residential	7603	10	21					
83	Residential	8085	21	34					
84	Lawn	8736	31	30	35	21			
85	Residential	9911	40	23					
86	Residential	11331	47	28	28	27			
87	Residential	13009	55	23					
88	Right-of-way	13274	45	26					
89	Residential	11406	35	25	26	22			
90	Residential	9879	21	38					
91	Residential	9385	11	27					
150	Residential	1745	21	355					
151	Woodlot	2351	19	***160***					
**157	Residential	1749	21	***140***	***200***	***130***	***96***	60	27
158	Tilled	1775	23	***130***	***125***	***125***	***130***	***103***	29
159	Residential	7665	29	30					
160	Untilled	7695	29	39	39	31	23	21	22
161	Tilled	7594	30	29	26	22	14	14	19
162	Right-of-way	4601	26	25	26	25	23	16	16
163	Tilled	4604	26	24	25	24	22	24	26
164	Residential	11360	36	27	28	23	19	17	22
165	Tilled	11356	36	17	17	18	18	21	25

*Distance (meters) and direction (degrees) from INCO stack.
**Single samples only at Sites 59 and 157 (See text).
Data are average of duplicate samples, μg/g air-dry weight.
Bold italic data exceed Table F *Guideline* for copper in non-agricultural soils (85 μg/g Cu).
Shaded data exceed Table A *Guideline* for copper in fine-textured residential/parkland soil 300 μg/g Cu).

Appendix A-4: Concentrations of aluminum in soil collected in the Port Colborne area, 1998.

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
1	Residential	372	318	11500					
2	Boulevard	463	301	9750					
3	Residential	442	275	2700	2700	2750			
4	Residential	675	342	20000	22000	19000			
5	Boulevard	852	332	17000					
6	Residential	1083	329	12500					
7	Boulevard	882	6	12000					
8	Residential	1130	5	14000					
9	Residential	908	16	13000					
10	Boulevard	1387	32	6500					
11	School yard	2072	51	22500	25500	26500			
12	Right-of-way	3996	30	24000	29000	29000			
14	Residential	1030	113	8950	5750	2500			
15	Right-of-way	2134	83	15000					
16	Residential	2930	87	23500					
17	Right-of-way	245	243	9350	7650	8450			
19	Right-of-way	6557	33	17500	19500	18000			
20	Lawn	4593	91	23500					
23	Right-of-way	5457	3	24500					
24	Boulevard	304	323	9900					
25	Boulevard	1043	338	12500					
26	Boulevard	926	299	15500					
27	Boulevard	1279	306	5550					
28	Right-of-way	364	185	7500					
29	Boulevard	1278	337	10350					
30	Lawn	3602	289	17000					
31	Right-of-way	2450	8	13500					
32	Park	2654	357	23000					
33	Park	1991	341	25500	24500	22500			
34	Boulevard	1215	293	18500					
35	Park	2292	330	16500					
36	Park	1755	314	16500					
37	Park	1253	275	4550	3500	2650			
38	Boulevard	2013	288	11000					
39	Residential	9547	276	11500	12500	13000			
40	Lawn	9438	262	15500					
41	Right-of-way	6114	264	15000					
42	Residential	4465	268	9550					
43	Right-of-way	2244	107	7600	7450	4750			
44	Residential	6206	89	14500					
45	Right-of-way	9522	93	16500	17500	18500			
46	Right-of-way	10254	81	18000					
47	Residential	7131	78	11000					
48	Lawn	6244	77	19000					
49	Residential	4868	71	18000	19000	19500			
50	Residential	3192	66	17000	17500	18500			
51	Residential	1973	42	18500	24000	26500			
52	Lawn	3058	294	15000					
53	Lawn	4527	286	16500	16000	17000			
54	Right-of-way	6224	281	18500					
55	Residential	7933	278	20000	19500	23500			
56	Residential	9818	288	14500					
58	Residential	5305	300	17500					

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
59	Residential	4487	319	16500					
60	Residential	3571	338	16000					
61	Residential	3576	11	19250					
62	Residential	5602	55	14000	14500	14000			
63	Cemetery	5292	50	14500	15500	17000			
64	Lawn	6361	57	22500					
65	Residential	7040	63	11500					
66	Residential	8295	65	13000					
67	Residential	9516	68	20000					
68	Residential	11265	73	16500					
69	Residential	11911	63	21500					
70	Residential	10747	52	24000					
71	Residential	7587	44	15000					
72	Residential	5894	21	22000	22500	22500			
73	Lawn	4939	345	23500					
74	Residential	6872	330	18000					
75	Residential	7579	321	24500					
76	Residential	8640	305	13500					
77	Residential	10824	296	13000					
78	Right-of-way	11373	308	15000					
79	Right-of-way	10218	315	17500					
80	Residential	8825	325	14500					
81	Residential	7795	344	16500					
82	Residential	7603	10	18500					
83	Residential	8085	21	18000					
84	Lawn	8736	31	24500	26500	24500			
85	Residential	9911	40	20500					
86	Residential	11331	47	25000	25500	25500			
87	Residential	13009	55	20000					
88	Right-of-way	13274	45	16000					
89	Residential	11406	35	17000	19500	19500			
90	Residential	9879	21	23500					
91	Residential	9385	11	25500					
150	Residential	1745	21	14000					
151	Woodlot	2351	19	24500					
**157	Residential	1749	21	16000	21000	20000	19000	15000	14000
158	Tilled	1775	23	24500	24000	22500	23000	26500	28500
159	Lawn	7665	29	14500					
160	Untilled	7695	29	20000	22500	23500	28500	31000	32500
161	Tilled	7594	30	26000	28000	32000	30500	32500	37000
162	Right-of-way	4601	26	13000	13500	14000	15000	16000	17500
163	Tilled	4604	26	15500	16500	14500	16500	23000	25500
164	Residential	11360	36	18000	21000	24500	28000	30500	32000
165	Tilled	11356	36	23000	23000	23500	24500	29000	30500

*Distance (meters) and direction (degrees) from INCO stack.
**Single samples only at Site 157 (See text).
Data are average of duplicate samples, μg/g air-dry weight.
Shaded data exceed OTR_{98} *Guideline* for aluminum in rural parkland soils (30000 μg/g Al), OTR_{98} Guideline is used because no clean-up guidelines have been developed for aluminum.

Appendix A-5 Concentrations of barium in soil collected in the Port Colborne area, 1998.

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
1	Residential	372	318	120					
2	Boulevard	463	301	105					
3	Residential	442	275	39	38	37			
4	Residential	675	342	210	***250***	***265***			
5	Boulevard	852	332	120					
6	Residential	1083	329	82					
7	Boulevard	882	6	67					
8	Residential	1130	5	108					
9	Residential	908	16	104					
10	Boulevard	1387	32	55					
11	School yard	2072	51	130	140	150			
12	Right-of-way	3996	30	160	190	190			
14	Residential	1030	113	54	31	12			
15	Right-of-way	2134	83	92					
16	Residential	2930	87	140					
17	Right-of-way	245	243	39	33	37			
19	Right-of-way	6557	33	79	85	76			
20	Lawn	4593	91	130					
23	Right-of-way	5457	3	110					
24	Boulevard	304	323	99					
25	Boulevard	1043	338	80					
26	Boulevard	926	299	110					
27	Boulevard	1279	306	39					
28	Right-of-way	364	185	51					
29	Boulevard	1278	337	91					
30	Lawn	3602	289	86					
31	Right-of-way	2450	8	76					
32	Park	2654	357	105					
33	Park	1991	341	140	140	135			
34	Boulevard	1215	293	125					
35	Park	3308	287	190					
36	Park	1755	314	87					
37	Park	1253	275	63	38	39			
38	Boulevard	2013	288	64					
39	Residential	9547	276	59	62	63			
40	Lawn	9438	262	99					
41	Right-of-way	6114	264	91					
42	Residential	4465	268	42					
43	Right-of-way	2244	107	47	44	21			
44	Residential	6206	89	67					
45	Right-of-way	9522	93	83	86	88			
46	Right-of-way	10254	81	105					
47	Residential	7131	78	66					
48	Lawn	6244	77	105					
49	Residential	4868	71	100	105	105			
50	Residential	3192	66	92	96	98			
51	Residential	1973	42	115	125	135			
52	Lawn	3058	294	86					
53	Lawn	4527	286	74	72	75			
54	Right-of-way	6224	281	115					
55	Residential	7933	278	140	145	145			
56	Residential	9818	288	91					
58	Residential	5305	300	100					

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
59	Residential	4487	319	98					
60	Residential	3571	338	74					
61	Residential	3576	11	96					
62	Residential	5602	55	87	92	93			
63	Cemetery	5292	50	67	70	75			
64	Lawn	6361	57	120					
65	Residential	7040	63	65					
66	Residential	8295	65	66					
67	Residential	9516	68	93					
68	Residential	11265	73	92					
69	Residential	11911	63	110					
70	Residential	10747	52	115					
71	Residential	7587	44	91					
72	Residential	5894	21	81	92	87			
73	Lawn	4939	345	140					
74	Residential	6872	330	110					
75	Residential	7579	321	140					
76	Residential	8640	305	20					
77	Residential	10824	296	87					
78	Right-of-way	11373	308	71					
79	Right-of-way	10218	315	98					
80	Residential	8825	325	89					
81	Residential	7795	344	86					
82	Residential	7603	10	105					
83	Residential	8085	21	***240***					
84	Lawn	8736	31	130	140	130			
85	Residential	9911	40	90					
86	Residential	11331	47	140	150	145			
87	Residential	13009	55	96					
88	Right-of-way	13274	45	82					
89	Residential	11406	35	110	120	125			
90	Residential	9879	21	145					
91	Residential	9385	11	130					
150	Residential	1745	21	***225***					
151	Woodlot	2351	19	120					
**157	Residential	1749	21	99	130	110	99	71	58
158	Tilled	1775	23	140	140	135	135	160	185
159	Lawn	7665	29	94					
160	Untilled	7695	29	120	130	130	135	150	190
161	Tilled	7594	30	115	120	130	120	120	150
162	Right-of-way	4601	26	70	71	70	71	71	85
163	Tilled	4604	26	89	93	85	95	140	170
164	Residential	11360	36	130	165	140	145	155	200
165	Tilled	11356	36	105	110	110	125	180	210

*Distance (meters) and direction (degrees) from INCO stack.
**Single samples only at Site 157 (See text).
Data are average of duplicate samples, μg/g air-dry weight.
Bold italic data exceed Table F *Guideline* for barium in non-agricultural soils (210 μg/g Ba).
Shaded data exceed Table A *Guideline* for barium in fine-textured residential/parkland soil (1000 μg/g Ba).

Appendix A-6: Concentrations of beryllium in soil collected in the Port Colborne area, 1998.

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
1	Residential	372	318	0.7					
2	Boulevard	463	301	0.6					
3	Residential	442	275	0.5	0.5	0.5			
4	Residential	675	342	1.0	1.1	1.1			
5	Boulevard	852	332	0.9					
6	Residential	1083	329	0.6					
7	Boulevard	882	6	0.5					
8	Residential	1130	5	0.6					
9	Residential	908	16	0.6					
10	Boulevard	1387	32	0.5					
11	School yard	2072	51	1.0	1.1	1.2			
12	Right-of-way	3996	30	1.1	1.3	1.3			
14	Residential	1030	113	0.5	0.5	0.6			
15	Right-of-way	2134	83	0.6					
16	Residential	2930	87	1.0					
17	Right-of-way	245	243	0.5	0.5	0.5			
19	Right-of-way	6557	33	0.7	0.7	0.7			
20	Lawn	4593	91	1.0					
23	Right-of-way	5457	3	1.0					
24	Boulevard	304	323	0.6					
25	Boulevard	1043	338	0.6					
26	Boulevard	926	299	0.8					
27	Boulevard	1279	306	0.5					
28	Right-of-way	364	185	0.5					
29	Boulevard	1278	337	0.6					
30	Lawn	3602	289	0.7					
31	Right-of-way	2450	8	0.6					
32	Park	2654	357	1.1					
33	Park	1991	341	1.0	1.0	1.0			
34	Boulevard	1215	293	1.0					
35	Park	3308	287	0.8					
36	Park	1755	314	0.7					
37	Park	1253	275	0.5	0.5	0.5			
38	Boulevard	2013	288	0.6					
39	Residential	9547	276	0.5	0.5	0.5			
40	Lawn	9438	262	0.7					
41	Right-of-way	6114	264	0.7					
42	Residential	4465	268	0.5					
43	Right-of-way	2244	107	0.5	0.5	0.5			
44	Residential	6206	89	0.6					
45	Right-of-way	9522	93	0.7	0.7	0.8			
46	Right-of-way	10254	81	0.8					
47	Residential	7131	78	0.5					
48	Lawn	6244	77	0.8					
49	Residential	4868	71	0.7	0.8	0.8			
50	Residential	3192	66	0.8	0.6	0.6			
51	Residential	1973	42	0.8	0.9	1.0			
52	Lawn	3058	294	0.8					
53	Lawn	4527	286	0.6	0.6	0.6			
54	Right-of-way	6224	281	0.9					
55	Residential	7933	278	0.7	0.7	0.8			
56	Residential	9818	288	0.5					
58	Residential	5305	300	0.8					

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
59	Residential	4487	319	0.8					
60	Residential	3571	338	0.6					
61	Residential	3576	11	0.8					
62	Residential	5602	55	0.6	0.7	0.7			
63	Cemetery	5292	50	0.6	0.6	0.7			
64	Lawn	6361	57	0.9					
65	Residential	7040	63	0.5					
66	Residential	8295	65	0.5					
67	Residential	9516	68	0.7					
68	Residential	11265	73	0.6					
69	Residential	11911	63	1.0					
70	Residential	10747	52	0.9					
71	Residential	7587	44	0.7					
72	Residential	5894	21	0.9	0.9	0.9			
73	Lawn	4939	345	1.1					
74	Residential	6872	330	0.8					
75	Residential	7579	321	1.2					
76	Residential	8640	305	0.5					
77	Residential	10824	296	0.5					
78	Right-of-way	11373	308	0.5					
79	Right-of-way	10218	315	0.6					
80	Residential	8825	325	0.5					
81	Residential	7795	344	0.5					
82	Residential	7603	10	0.9					
83	Residential	8085	21	0.8					
84	Lawn	8736	31	1.0	1.0	0.9			
85	Residential	9911	40	0.7					
86	Residential	11331	47	1.0	1.1	1.0			
87	Residential	13009	55	0.8					
88	Right-of-way	13274	45	0.6					
89	Residential	11406	35	0.6	0.7	0.7			
90	Residential	9879	21	1.1					
91	Residential	9385	11	0.9					
150	Residential	1745	21	0.8					
151	Woodlot	2351	19	0.9					
**157	Residential	1749	21	0.7	0.9	1.1	0.8	0.6	0.5
158	Tilled	1775	23	1.0	1.0	1.0	1.0	1.1	1.2
159	Lawn	7665	29	0.6					
160	Untilled	7695	29	0.8	0.9	0.9	1.1	1.4	1.5
161	Tilled	7594	30	0.9	0.9	0.9	0.8	0.9	1.2
162	Right-of-way	4601	26	0.5	0.5	0.5	0.5	0.5	0.7
163	Tilled	4604	26	0.6	0.6	0.6	0.6	0.9	1.0
164	Residential	11360	36	0.7	0.7	0.8	1.0	1.3	1.6
165	Tilled	11356	36	0.8	0.9	0.9	1.0	1.3	1.5

*Distance (meters) and direction (degrees) from INCO stack.
**Single samples only at Site 157 (See text).
Data are average of duplicate samples, μg/g air-dry weight.
Bold italic data exceed Table F *Guideline* for beryllium in non-agricultural soils (1.2 μg/g Be)
Shaded cells exceed Table A *Guideline* for beryllium in fine-textured residential/parkland soil (1.2 μg/g Be).

Appendix A-7 Concentrations of cadmium in soil collected in the Port Colborne area, 1998.

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
1	Residential	372	318	0.9					
2	Boulevard	463	301	1.0					
3	Residential	442	275	0.2	0.2	0.2			
4	Residential	675	342	***2.5***	3.5	4.8			
5	Boulevard	852	332	***1.1***					
6	Residential	1083	329	***4.4***					
7	Boulevard	882	6	0.7					
8	Residential	1130	5	0.9					
9	Residential	908	16	0.6					
10	Boulevard	1387	32	0.2					
11	School yard	2072	51	0.3	0.3	0.4			
12	Right-of-way	3996	30	0.3	0.4	0.4			
14	Residential	1030	113	0.3	0.2	0.2			
15	Right-of-way	2134	83	0.9					
16	Residential	2930	87	1.0					
17	Right-of-way	245	243	0.4	0.3	0.2			
19	Right-of-way	6557	33	0.4	0.4	0.3			
20	Lawn	4593	91	0.6					
23	Right-of-way	5457	3	0.3					
24	Boulevard	304	323	0.2					
25	Boulevard	1043	338	***1.1***					
26	Boulevard	926	299	0.9					
27	Boulevard	1279	306	0.2					
28	Right-of-way	364	185	0.6					
29	Boulevard	1278	337	0.5					
30	Lawn	3602	289	0.7					
31	Right-of-way	2450	8	0.5					
32	Park	2654	357	0.8					
33	Park	1991	341	0.7	0.7	0.8			
34	Boulevard	1215	293	***1.1***					
35	Park	3308	287	***1.8***					
36	Park	1755	314	0.6					
37	Park	1253	275	0.5	0.4	0.2			
38	Boulevard	2013	288	0.6					
39	Residential	9547	276	0.3	0.4	0.4			
40	Lawn	9438	262	0.5					
41	Right-of-way	6114	264	0.4					
42	Residential	4465	268	0.3					
43	Right-of-way	2244	107	0.3	0.3	0.2			
44	Residential	6206	89	0.5					
45	Right-of-way	9522	93	0.9	0.8	0.9			
46	Right-of-way	10254	81	0.8					
47	Residential	7131	78	0.4					
48	Lawn	6244	77	0.3					
49	Residential	4868	71	0.6	0.6	0.6			
50	Residential	3192	66	0.6	0.7	0.7			
51	Residential	1973	42	0.4	0.5	0.4			
52	Lawn	3058	294	0.5					
53	Lawn	4527	286	0.7	0.7	0.8			
54	Right-of-way	6224	281	0.5					
55	Residential	7933	278	0.5	1.0	0.8			
56	Residential	9818	288	0.2					
58	Residential	5305	300	0.5					

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
59	Residential	4487	319	0.9					
60	Residential	3571	338	0.4					
61	Residential	3576	11	0.4					
62	Residential	5602	55	0.7	0.7	0.6			
63	Cemetery	5292	50	0.5	0.6	0.7			
64	Lawn	6361	57	1.0					
65	Residential	7040	63	0.4					
66	Residential	8295	65	0.3					
67	Residential	9516	68	0.5					
68	Residential	11265	73	0.6					
69	Residential	11911	63	0.3					
70	Residential	10747	52	0.6					
71	Residential	7587	44	0.4					
72	Residential	5894	21	0.3	0.3	0.5			
73	Lawn	4939	345	***1.2***					
74	Residential	6872	330	0.9					
75	Residential	7579	321	***1.3***					
76	Residential	8640	305	0.2					
77	Residential	10824	296	0.2					
78	Right-of-way	11373	308	0.2					
79	Right-ot-way	10218	315	0.2					
80	Residential	8825	325	0.2					
81	Residential	7795	344	0.4					
82	Residential	7603	10	0.5					
83	Residential	8085	21	1.0					
84	Lawn	8736	31	0.4	0.4	0.4			
85	Residential	9911	40	0.4					
86	Residential	11331	47	0.6	0.5	0.5			
87	Residential	13009	55	0.4					
88	Right-of-way	13274	45	0.5					
89	Residential	11406	35	0.4	0.4	0.4			
90	Residential	9879	21	0.6					
91	Residential	9385	11	0.8					
150	Residential	1745	21	0.2					
151	Woodlot	2351	19	0.5					
**157	Residential	1749	21	1.0	0.6	0.2	0.4	0.2	0.3
158	Tilled	1775	23	0.2	0.4	0.3	0.3	0.4	0.3
159	Lawn	7665	29	0.4					
160	Untilled	7695	29	0.8	0.9	0.5	0.3	0.2	0.2
161	Tilled	7594	30	0.4	0.5	0.4	0.2	0.2	0.2
162	Right-of-way	4601	26	0.3	0.3	0.3	0.3	0.2	0.2
163	Tilled	4604	26	0.3	0.3	0.2	0.3	0.3	0.3
164	Residential	11360	36	0.9	0.8	0.6	0.4	0.2	0.4
165	Tilled	11356	36	0.4	0.4	0.6	0.2	0.3	0.4

*Distance (meters) and direction (degrees) from INCO stack.
**Single samples only at Site 157 (See text).
Data are average of duplicate samples, μg/g air-dry weight.
Bold italic data exceed Table F *Guideline* for cadmium in non-agricultural soils (1.0 μg/g Cd).
Shaded data exceed Table A *Guideline* for cadmium in fine-textured residential/parkland soil (12 μg/g Cd).

Appendix A-8: Concentrations of calcium in soil collected in the Port Colborne area, 1998.

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
1	Residential	2930	87	27500					
2	Boulevard	245	243	64000					
3	Residential	11911	63	27500	28000	28000			
4	Residential	10747	52	20500	19500	20000			
5	Boulevard	6557	33	17000					
6	Residential	4593	91	14000					
7	Boulevard	3996	30	18000					
8	Residential	2072	51	31500					
9	Residential	1030	113	13000					
10	Boulevard	1387	32	29000					
11	School yard	4939	345	8500	7350	6950			
12	Right-of-way	6872	330	34500	42000	49500			
14	Residential	5894	21	15500	21000	33500			
15	Right-of-way	304	323	9200					
16	Residential	1043	338	6150					
17	Right-of-way	7587	44	6650	14850	17900			
19	Right-of-way	11406	35	5000	5900	3900			
20	Lawn	926	299	4650					
23	Right-of-way	1279	306	6900					
24	Boulevard	364	185	29000					
25	Boulevard	2134	83	25500					
26	Boulevard	372	318	23000					
27	Boulevard	442	275	39500					
28	Right-of-way	5457	3	19000					
29	Boulevard	11265	73	45000					
30	Lawn	1083	329	9900					
31	Right-of-way	908	16	16500					
32	Park	1130	5	7950					
33	Park	7795	344	6300	9900	8750			
34	Boulevard	463	301	22000					
35	Park	882	6	5750					
36	Park	852	332	7350					
37	Park	8825	325	7300	7300	8900			
38	Boulevard	675	342	16500					
39	Residential	10824	296	10350	9050	8350			
40	Lawn	1991	341	2700					
41	Right-of-way	2450	8	8500					
42	Residential	2654	357	7200					
43	Right-of-way	8085	21	19500	20000	22000			
44	Residential	7131	78	4150					
45	Right-of-way	11331	47	5950	5650	5450			
46	Right-of-way	3192	66	23500					
47	Residential	4868	71	9000					
48	Lawn	6244	77	5450					
49	Residential	9911	40	16000	12500	11400			
50	Residential	8736	31	6250	6000	6350			
51	Residential	7603	10	7650	4600	3350			
52	Lawn	1278	337	4950					
53	Lawn	10218	315	5050	3100	2500			
54	Right-of-way	3602	289	9000					
55	Residential	11373	308	15500	11000	7550			
56	Residential	1215	293	22000					
58	Residential	10254	81	7500					

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
59	Residential	9522	93	12000					
60	Residential	6206	89	5800					
61	Residential	4487	319	15000					
62	Residential	13274	45	7450	8550	8250			
63	Cemetery	13009	55	5000	3700	3900			
64	Lawn	3571	338	5400					
65	Residential	5305	300	13500					
66	Residential	9818	288	15000					
67	Residential	7933	278	6800					
68	Residential	1973	42	4450					
69	Residential	3058	294	12500					
70	Residential	3576	11	7600					
71	Residential	5292	50	6100					
72	Residential	9879	21	6750	9200	7700			
73	Lawn	2244	107	12000					
74	Residential	4465	268	17500					
75	Residential	1253	275	6750					
76	Residential	3308	287	21000					
77	Residential	1755	314	18000					
78	Right-of-way	9547	276	19000					
79	Right-of-way	9438	262	42000					
80	Residential	2013	288	20000					
81	Residential	6114	264	12500					
82	Residential	7040	63	16500					
83	Residential	6361	57	26000					
84	Lawn	9385	11	5650	4800	4600			
85	Residential	5602	55	4650					
86	Residential	1745	21	18500	23500	19000			
87	Residential	4527	286	7200					
88	Right-of-way	6224	281	7750					
89	Residential	1749	21	10500	9950	8150			
90	Residential	9516	68	8900					
91	Residential	8295	65	6100					
150	Residential	7579	321	11500					
151	Woodlot	2351	19	4600					
**157	Residential	8640	305	6000	5000	4200	4700	5600	5000
158	Tilled	1775	23	32250	5550	5200	5400	4850	4200
159	Lawn	7665	29	9850					
160	Untilled	7695	29	14000	12250	8950	5600	4550	6200
161	Tilled	7594	30	7300	5550	4750	2500	1900	2150
162	Right-of-way	4601	26	8000	7250	6200	4950	3600	3250
163	Tilled	4604	26	11500	11000	12000	12500	9650	9650
164	Residential	11360	36	6650	6250	4450	4200	2900	3150
165	Tilled	11356	36	2850	2850	2750	2650	2650	3050

*Distance (meters) and direction (degrees) from INCO stack.
**Single samples only at Site 157 (See text).
Data are average of duplicate samples, μg/g air-dry weight.
Shaded exceed OTR_{98} Guideline for calcium in rural parkland soils (55000 μg/g Ca), OTR_{98} Guideline is used because no clean-up guideline has been developed for calcium.

Appendix A-9: Concentrations of chromium in soil collected in the Port Colborne area, 1998.

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
1	Residential	372	318	26					
2	Boulevard	463	301	21					
3	Residential	442	275	15	14	15			
4	Residential	675	342	54	71	***83***			
5	Boulevard	852	332	24					
6	Residential	1083	329	19					
7	Boulevard	882	6	20					
8	Residential	1130	5	23					
9	Residential	908	16	20					
10	Boulevard	1387	32	12					
11	School yard	2072	51	31	32	33			
12	Right-of-way	3996	30	31	36	36			
14	Residential	1030	113	17	12	7			
15	Right-of-way	2134	83	21					
16	Residential	2930	87	28					
17	Right-of-way	245	243	12	12	12			
19	Right-of-way	6557	33	22	24	28			
20	Lawn	4593	91	28					
23	Right-of-way	5457	3	32					
24	Boulevard	304	323	21					
25	Boulevard	1043	338	21					
26	Boulevard	926	299	24					
27	Boulevard	1279	306	12					
28	Right-of-way	364	185	14					
29	Boulevard	1278	337	34					
30	Lawn	3602	289	22					
31	Right-of-way	2450	8	21					
32	Park	2654	357	28					
33	Park	1991	341	30	30	29			
34	Boulevard	1215	293	27					
35	Park	3308	287	39					
36	Park	1755	314	24					
37	Park	1253	275	14	9	7			
38	Boulevard	2013	288	22					
39	Residential	9547	276	15	17	17			
40	Lawn	9438	262	22					
41	Right-of-way	6114	264	20					
42	Residential	4465	268	14					
43	Right-of-way	2244	107	16	14	12			
44	Residential	6206	89	17					
45	Right-of-way	9522	93	21	23	24			
46	Right-of-way	10254	81	22					
47	Residential	7131	78	15					
48	Lawn	6244	77	24					
49	Residential	4868	71	23	25	24			
50	Residential	3192	66	24	29	24			
51	Residential	1973	42	26	29	32			
52	Lawn	3058	294	20					
53	Lawn	4527	286	23	22	23			
54	Right-of-way	6224	281	24					
55	Residential	7933	278	24	24	27			
56	Residential	9818	288	21					
58	Residential	5305	300	23					

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
59	Residential	4487	319	22					
60	Residential	3571	338	20					
61	Residential	3576	11	24					
62	Residential	5602	55	21	21	21			
63	Cemetery	5292	50	18	20	21			
64	Lawn	6361	57	27					
65	Residential	7040	63	17					
66	Residential	8295	65	16					
67	Residential	9516	68	26					
68	Residential	11265	73	21					
69	Residential	11911	63	29					
70	Residential	10747	52	30					
71	Residential	7587	44	21					
72	Residential	5894	21	37	31	31			
73	Lawn	4939	345	32					
74	Residential	6872	330	24					
75	Residential	7579	321	34					
76	Residential	8640	305	23					
77	Residential	10824	296	21					
78	Right-of-way	11373	308	20					
79	Right-of-way	10218	315	25					
80	Residential	8825	325	21					
81	Residential	7795	344	22					
82	Residential	7603	10	27					
83	Residential	8085	21	30					
84	Lawn	8736	31	41	48	29			
85	Residential	9911	40	26					
86	Residential	11331	47	33	35	32			
87	Residential	13009	55	26					
88	Right-of-way	13274	45	21					
89	Residential	11406	35	21	23	23			
90	Residential	9879	21	31					
91	Residential	9385	11	32					
150	Residential	1745	21	26					
151	Woodlot	2351	19	28					
157	Residential	1749	21	23	28	24	23	17	17
158	Tilled	1775	23	33	28	28	28	31	33
159	Lawn	7665	29	22					
160	Untilled	7695	29	29	32	31	37	39	41
161	Tilled	7594	30	33	33	36	36	39	44
162	Right-of-way	4601	26	21	18	17	19	18	22
163	Tilled	4604	26	20	23	20	20	30	31
164	Residential	11360	36	25	27	30	42	36	48
165	Tilled	11356	36	28	28	29	30	36	39

*Distance (meters) and direction (degrees) from INCO stack.
**Single samples only at Site 157 (See text).
Data are average of duplicate samples, μg/g air-dry weight.
Bold italic data exceed Table F *Guideline* for chromium in non-agricultural soils (71 μg/g Cr).
Shaded data exceed Table A *Guideline* for chromium in fine-textured residential/parkland soil (1000 μg/g Cr).

Appendix A-10: Concentrations of iron in soil collected in the Port Colborne area, 1998.

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
1	Residential	372	318	27000					
2	Boulevard	463	301	21500					
3	Residential	442	275	29500	27500	30500			
4	Residential	675	342	22500	25500	25500			
5	Boulevard	852	332	21500					
6	Residential	1083	329	18500					
7	Boulevard	882	6	15500					
8	Residential	1130	5	17000					
9	Residential	908	16	17500					
10	Boulevard	1387	32	12500					
11	School yard	2072	51	30500	34500	36500			
12	Right-of-way	3996	30	31000	35000	35500			
14	Residential	1030	113	15000	13000	10300			
15	Right-of-way	2134	83	16500					
16	Residential	2930	87	15500					
17	Right-of-way	245	243	14500	17500	14500			
19	Right-of-way	6557	33	20000	21000	20000			
20	Lawn	4593	91	18500					
23	Right-of-way	5457	3	28000					
24	Boulevard	304	323	22500					
25	Boulevard	1043	338	17000					
26	Boulevard	926	299	14000					
27	Boulevard	1279	306	12000					
28	Right-of-way	364	185	16500					
29	Boulevard	1278	337	17500					
30	Lawn	3602	289	19000					
31	Right-of-way	2450	8	16500					
32	Park	2654	357	18000					
33	Park	1991	341	29500	25500	24000			
34	Boulevard	1215	293	15000					
35	Park	3308	287	21000					
36	Park	1755	314	20500					
37	Park	1253	275	15000	7550	5700			
38	Boulevard	2013	288	14000					
39	Residential	9547	276	14000	15000	15500			
40	Lawn	9438	262	20000					
41	Right-of-way	6114	264	18000					
42	Residential	4465	268	14500					
43	Right-of-way	2244	107	17500	16500	14500			
44	Residential	6206	89	11500					
45	Right-of-way	9522	93	19500	21000	21500			
46	Right-of-way	10254	81	18500					
47	Residential	7131	78	13500					
48	Lawn	6244	77	22500					
49	Residential	4868	71	20000	21500	22000			
50	Residential	3192	66	19500	21500	22500			
51	Residential	1973	42	21000	21500	24000			
52	Lawn	3058	294	18000					
53	Lawn	4527	286	20000	20500	21500			
54	Right-of-way	6224	281	23000					
55	Residential	7933	278	15500	14000	14500			
56	Residential	9818	288	15000					
58	Residential	5305	300	21000					

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
59	Residential	4487	319	18500					
60	Residential	3571	338	17000					
61	Residential	3576	11	19500					
62	Residential	5602	55	19000	19500	19500			
63	Cemetery	5292	50	19000	20000	20000			
64	Lawn	6361	57	21000					
65	Residential	7040	63	14500					
66	Residential	8295	65	13500					
67	Residential	9516	68	25000					
68	Residential	11265	73	18500					
69	Residential	11911	63	28000					
70	Residential	10747	52	26500					
71	Residential	7587	44	12000					
72	Residential	5894	21	24000	25500	25500			
73	Lawn	4939	345	23000					
74	Residential	6872	330	18500					
75	Residential	7579	321	15000					
76	Residential	8640	305	14000					
77	Residential	10824	296	14500					
78	Right-of-way	11373	308	16000					
79	Right-of-way	10218	315	20000					
80	Residential	8825	325	16500					
81	Residential	7795	344	17500					
82	Residential	7603	10	21500					
83	Residential	8085	21	24000					
84	Lawn	8736	31	28500	32500	16500			
85	Residential	9911	40	23500					
86	Residential	11331	47	30000	33500	32000			
87	Residential	13009	55	25500					
88	Right-of-way	13274	45	16500					
89	Residential	11406	35	17500	19000	19500			
90	Residential	9879	21	26500					
91	Residential	9385	11	16000					
150	Residential	1745	21	22000					
151	Woodlot	2351	19	16000					
**157	Residential	1749	21	20000	24000	22000	21000	17000	15000
158	Tilled	1775	23	26000	26500	26000	26000	29500	32000
159	Lawn	7665	29	19000					
160	Untilled	7695	29	23500	26000	27500	35000	36500	42500
161	Tilled	7594	30	19500	18500	21500	23500	27500	32500
162	Right-of-way	4601	26	16000	15500	15500	16500	17000	19500
163	Tilled	4604	26	17500	17500	16500	17500	24500	26500
164	Residential	11360	36	19500	21500	26000	30500	34500	37500
165	Tilled	11356	36	28500	29000	29500	31500	37500	40000

*Distance (meters) and direction (degrees) from INCO stack.
**Single samples only at Site 157 (See text).
Data are average of duplicate samples, μg/g air-dry weight.
Shaded data exceed OTR_{98} Guideline for iron in rural parkland soils (35000 μg/g Fe), OTR_{98} Guideline is used because no clean-up guidelines have been developed for iron.

Appendix A-11: Concentrations of lead in soil collected in the Port Colborne area, 1998.

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
1	Residential	372	318	***155***					
2	Boulevard	463	301	***130***					
3	Residential	442	275	57	57	60			
4	Residential	675	342	108	120	***145***			
5	Boulevard	852	332	64					
6	Residential	1083	329	73					
7	Boulevard	882	6	32					
8	Residential	1130	5	62					
9	Residential	908	16	59					
10	Boulevard	1387	32	9					
11	School yard	2072	51	32	36	33			
12	Right-of-way	3996	30	19	17	14			
14	Residential	1030	113	29	17	7			
15	Right-of-way	2134	83	48					
16	Residential	2930	87	26					
17	Right-of-way	245	243	27	23	16			
19	Right-of-way	6557	33	25	26	21			
20	Lawn	4593	91	27					
23	Right-of-way	5457	3	22					
24	Boulevard	304	323	98					
25	Boulevard	1043	338	73					
26	Boulevard	926	299	79					
27	Boulevard	1279	306	15					
28	Right-of-way	364	185	57					
29	Boulevard	1278	337	***170***					
30	Lawn	3602	289	53					
31	Right-of-way	2450	8	50					
32	Park	2654	357	37					
33	Park	1991	341	22	31	46			
34	Boulevard	1215	293	78					
35	Park	3308	287	62					
36	Park	1755	314	32					
37	Park	1253	275	86	64	86			
38	Boulevard	2013	288	29					
39	Residential	9547	276	46	46	38			
40	Lawn	9438	262	22					
41	Right-of-way	6114	264	48					
42	Residential	4465	268	21					
43	Right-of-way	2244	107	24	18	5			
44	Residential	6206	89	27					
45	Right-of-way	9522	93	36	38	29			
46	Right-of-way	10254	81	34					
47	Residential	7131	78	52					
48	Lawn	6244	77	36					
49	Residential	4868	71	50	51	41			
50	Residential	3192	66	27	29	28			
51	Residential	1973	42	54	25	20			
52	Lawn	3058	294	58					
53	Lawn	4527	286	36	31	18			
54	Right-of-way	6224	281	30					
55	Residential	7933	278	61	59	27			
56	Residential	9818	288	16					
58	Residential	5305	300	28					

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
59	Residential	4487	319	80					
60	Residential	3571	338	23					
61	Residential	3576	11	30					
62	Residential	5602	55	101	74	79			
63	Cemetery	5292	50	38	34	26			
64	Lawn	6361	57	25					
65	Residential	7040	63	62					
66	Residential	8295	65	23					
67	Residential	9516	68	102					
68	Residential	11265	73	43					
69	Residential	11911	63	27					
70	Residential	10747	52	46					
71	Residential	7587	44	21					
72	Residential	5894	21	22	21	18			
73	Lawn	4939	345	45					
74	Residential	6872	330	32					
75	Residential	7579	321	28					
76	Residential	8640	305	20					
77	Residential	10824	296	91					
78	Right-of-way	11373	308	62					
79	Right-of-way	10218	315	25					
80	Residential	8825	325	19					
81	Residential	7795	344	26					
82	Residential	7603	10	30					
83	Residential	8085	21	210					
84	Lawn	8736	31	24	22	21			
85	Residential	9911	40	29					
86	Residential	11331	47	34	30	26			
87	Residential	13009	55	32					
88	Right-of-way	13274	45	36					
89	Residential	11406	35	58	55	94			
90	Residential	9879	21	42					
91	Residential	9385	11	56					
150	Residential	1745	21	380					
151	Woodlot	2351	19	62					
157	Residential	1749	21	100	94	49	91	87	57
158	Tilled	1775	23	34	35	42	37	34	21
159	Lawn	7665	29	89					
160	Untilled	7695	29	115	110	83	41	24	18
161	Tilled	7594	30	23	22	19	14	14	14
162	Right-of-way	4601	26	32	33	21	17	17	16
163	Tilled	4604	26	27	26	26	23	21	21
164	Residential	11360	36	69	71	45	23	14	14
165	Tilled	11356	36	17	17	18	15	13	11

*Distance (meters) and direction (degrees) from INCO stack.
**Single samples only at Site 157 (See text).
Data are average of duplicate samples, μg/g air-dry weight.
Bold italic data exceed Table F *Guideline* for lead in non-agricultural soils (120 μg/g Pb).
Shaded data exceed Table A *Guideline* for lead in fine-textured residential/parkland soil (200 μg/g Pb).

Appendix A-12: Concentrations of magnesium in soil collected in the Port Colborne area, 1998.

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
1	Residential	372	318	12500					
2	Boulevard	463	301	34500					
3	Residential	442	275	6600	6850	6800			
4	Residential	675	342	7950	8550	8150			
5	Boulevard	852	332	9150					
6	Residential	1083	329	7400					
7	Boulevard	882	6	9500					
8	Residential	1130	5	5700					
9	Residential	908	16	5400					
10	Boulevard	1387	32	5800					
11	School yard	2072	51	6750	7200	7200			
12	Right-of-way	3996	30	13500	14500	15000			
14	Residential	1030	113	6250	5950	7550			
15	Right-of-way	2134	83	3750					
16	Residential	2930	87	4950					
17	Right-of-way	245	243	3250	4800	5500			
19	Right-of-way	6557	33	5150	5650	4650			
20	Lawn	4593	91	5500					
23	Right-of-way	5457	3	6350					
24	Boulevard	304	323	12500					
25	Boulevard	1043	338	12000					
26	Boulevard	926	299	11000					
27	Boulevard	1279	306	13500					
28	Right-of-way	364	185	7900					
29	Boulevard	1278	337	20000					
30	Lawn	3602	289	6750					
31	Right-of-way	2450	8	10400					
32	Park	2654	357	5600					
33	Park	1991	341	5300	6400	5700			
34	Boulevard	1215	293	10500					
35	Park	3308	287	5450					
36	Park	1755	314	5150					
37	Park	1253	275	2800	3050	2600			
38	Boulevard	2013	288	6950					
39	Residential	9547	276	6200	5450	4850			
40	Lawn	9438	262	12500					
41	Right-of-way	6114	264	6350					
42	Residential	4465	268	3750					
43	Right-of-way	2244	107	7550	6950	5150			
44	Residential	6206	89	2800					
45	Right-of-way	9522	93	4050	4150	4200			
46	Right-of-way	10254	81	7100					
47	Residential	7131	78	5150					
48	Lawn	6244	77	5050					
49	Residential	4868	71	10500	9350	9100			
50	Residential	3192	66	5150	5250	5950			
51	Residential	1973	42	5450	5400	5450			
52	Lawn	3058	294	4100					
53	Lawn	4527	286	4800	4200	4250			
54	Right-of-way	6224	281	6550					
55	Residential	7933	278	6450	4850	4400			
56	Residential	9818	288	8800					
58	Residential	5305	300	6600					

Site	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
59	Residential	4487	319	6000					
60	Residential	3571	338	4150					
61	Residential	3576	11	9750					
62	Residential	5602	55	4800	5400	5100			
63	Cemetery	5292	50	5000	4750	5200			
64	Lawn	6361	57	5150					
65	Residential	7040	63	5400					
66	Residential	8295	65	5050					
67	Residential	9516	68	5750					
68	Residential	11265	73	4050					
69	Residential	11911	63	8300					
70	Residential	10747	52	5950					
71	Residential	7587	44	3950					
72	Residential	5894	21	5200	5950	5650			
73	Lawn	4939	345	7100					
74	Residential	6872	330	5450					
75	Residential	7579	321	4650					
76	Residential	8640	305	6450					
77	Residential	10824	296	6700					
78	Right-of-way	11373	308	9750					
79	Right-of-way	10218	315	11500					
80	Residential	8825	325	8900					
81	Residential	7795	344	5300					
82	Residential	7603	10	7000					
83	Residential	8085	21	9250					
84	Lawn	8736	31	5600	5950	3950			
85	Residential	9911	40	5200					
86	Residential	11331	47	11000	11500	9800			
87	Residential	13009	55	6400					
88	Right-of-way	13274	45	5000					
89	Residential	11406	35	4350	4250	4100			
90	Residential	9879	21	6150					
91	Residential	9385	11	4350					
150	Residential	1745	21	4750					
151	Woodlot	2351	19	3450					
**157	Residential	1749	21	4400	5000	4400	4400	4000	3900
158	Tilled	1775	23	5600	5550	5250	5450	5900	6800
159	Lawn	7665	29	5350					
160	Untilled	7695	29	9000	9150	7500	8100	8950	9900
161	Tilled	7594	30	6150	5600	5900	5850	6450	7750
162	Right-of-way	4601	26	5550	5200	4700	4300	3900	4350
163	Tilled	4604	26	5550	5650	5450	5650	6950	9200
164	Residential	11360	36	4050	4400	4750	5800	6900	8550
165	Tilled	11356	36	4950	4950	5150	5700	7700	9100

*Distance (meters) and direction (degrees) from INCO stack.
**Single samples only at Site 157 (see text).
Data are average of duplicate samples, μg/g air-dry weight.
Shaded data exceed OTR_{98} Guideline for magnesium in rural parkland soils (20000 μg/g Mg), OTR_{98} Guideline is used because no clean-up guidelines have been developed for magnesium.

Appendix A-13 Concentrations of manganese in soil collected in the Port Colborne area, 1998

Station	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
1	Residential	372	318	485					
2	Boulevard	463	301	560					
3	Residential	442	275	585	440	385			
4	Residential	675	342	405	475	395			
5	Boulevard	852	332	280					
6	Residential	1083	329	415					
7	Boulevard	882	6	310					
8	Residential	1130	5	325					
9	Residential	908	16	415					
10	Boulevard	1387	32	460					
11	School yard	2072	51	580	840	880			
12	Right-of-way	3996	30	555	620	590			
14	Residential	1030	113	245	240	210			
15	Right-of-way	2134	83	235					
16	Residential	2930	87	190					
17	Right-of-way	245	243	195	225	205			
19	Right-of-way	6557	33	445	470	455			
20	Lawn	4593	91	235					
23	Right-of-way	5457	3	715					
24	Boulevard	304	323	465					
25	Boulevard	1043	338	365					
26	Boulevard	926	299	275					
27	Boulevard	1279	306	455					
28	Right-of-way	364	185	345					
29	Boulevard	1278	337	530					
30	Lawn	3602	289	510					
31	Right-of-way	2450	8	360					
32	Park	2654	357	245					
33	Park	1991	341	460	405	335			
34	Boulevard	1215	293	260					
35	Park	3308	287	650					
36	Park	1755	314	435					
37	Park	1253	275	270	185	150			
38	Boulevard	2013	288	430					
39	Residential	9547	276	330	345	375			
40	Lawn	9438	262	495					
41	Right-of-way	6114	264	670					
42	Residential	4465	268	250					
43	Right-of-way	2244	107	260	245	180			
44	Residential	6206	89	158					
45	Right-of-way	9522	93	485	520	510			
46	Right-of-way	10254	81	400					
47	Residential	7131	78	265					
48	Lawn	6244	77	330					
49	Residential	4868	71	320	285	300			
50	Residential	3192	66	370	460	485			
51	Residential	1973	42	365	210	185			
52	Lawn	3058	294	615					
53	Lawn	4527	286	205	160	150			
54	Right-of-way	6224	281	620					
55	Residential	7933	278	230	200	170			
56	Residential	9818	288	300					
58	Residential	5305	300	440					

Station	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
59	Residential	4487	319	560					
60	Residential	3571	338	235					
61	Residential	3576	11	340					
62	Residential	5602	55	440	445	460			
63	Cemetery	5292	50	590	605	655			
64	Lawn	6361	57	405					
65	Residential	7040	63	345					
66	Residential	8295	65	190					
67	Residential	9516	68	440					
68	Residential	11265	73	495					
69	Residential	11911	63	525					
70	Residential	10747	52	330					
71	Residential	7587	44	165					
72	Residential	5894	21	270	400	395			
73	Lawn	4939	345	525					
74	Residential	6872	330	430					
75	Residential	7579	321	255					
76	Residential	8640	305	280					
77	Residential	10824	296	355					
78	Right-of-way	11373	308	270					
79	Right-of-way	10218	315	515					
80	Residential	8825	325	375					
81	Residential	7795	344	355					
82	Residential	7603	10	395					
83	Residential	8085	21	470					
84	Lawn	8736	31	350	460	120			
85	Residential	9911	40	610					
86	Residential	11331	47	740	835	670			
87	Residential	13009	55	440					
88	Right-of-way	13274	45	295					
89	Residential	11406	35	295	350	325			
90	Residential	9879	21	385					
91	Residential	9385	11	310					
150	Residential	1745	21	910					
151	Woodlot	2351	19	220					
157	Residential	1749	21	400	520	500	390	310	310
158	Tilled	1775	23	465	500	535	505	610	700
159	Lawn	7665	29	320					
160	Untilled	7695	29	455	485	480	430	410	380
161	Tilled	7594	30	235	170	150	125	140	165
162	Right-of-way	4601	26	260	260	260	265	260	335
163	Tilled	4604	26	300	315	290	335	440	460
164	Residential	11360	36	280	280	250	265	365	465
165	Tilled	11356	36	355	365	410	480	690	615

Values reported represent average of duplicate samples, μg/g air-dry weight. Single samples only at Site 157 (See text)
Values shown in bold and shaded exceed OTR_{98} Guideline for manganese in rural parkland soils (1300 μg/g Al), OTR_{98} Guideline is used because no clean-up guidelines have been developed for manganese
*Distance (meters) and direction (degrees) from INCO stack

Appendix A-14 Concentrations of molybdenum in soil collected in the Port Colborne area, 1998

Station	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
1	Residential	372	318	0.5					
2	Boulevard	463	301	1.1					
3	Residential	442	275	1.1	0.9	1.2			
4	Residential	675	342	0.7	0.5	0.5			
5	Boulevard	852	332	0.6					
6	Residential	1083	329	0.5					
7	Boulevard	882	6	0.5					
8	Residential	1130	5	0.6					
9	Residential	908	16	0.5					
10	Boulevard	1387	32	0.5					
11	School yard	2072	51	0.5	0.6	0.5			
12	Right-of-way	3996	30	0.5	0.5	0.5			
14	Residential	1030	113	0.5	0.5	0.5			
15	Right-of-way	2134	83	0.5					
16	Residential	2930	87	0.5					
17	Right-of-way	245	243	0.5	0.5	0.5			
19	Right-of-way	6557	33	0.6	0.6	0.6			
20	Lawn	4593	91	0.5					
23	Right-of-way	5457	3	0.6					
24	Boulevard	304	323	0.6					
25	Boulevard	1043	338	0.5					
26	Boulevard	926	299	0.5					
27	Boulevard	1279	306	0.6					
28	Right-of-way	364	185	0.6					
29	Boulevard	1278	337	1.4					
30	Lawn	3602	289	0.5					
31	Right-of-way	2450	8	0.5					
32	Park	2654	357	0.5					
33	Park	1991	341	0.5	0.5	0.5			
34	Boulevard	1215	293	0.5					
35	Park	3308	287	0.5					
36	Park	1755	314	0.5					
37	Park	1253	275	0.5	0.5	0.5			
38	Boulevard	2013	288	0.5					
39	Residential	9547	276	0.5	0.5	0.5			
40	Lawn	9438	262	0.5					
41	Right-of-way	6114	264	0.5					
42	Residential	4465	268	0.5					
43	Right-of-way	2244	107	0.5	0.5	0.5			
44	Residential	6206	89	0.5					
45	Right-of-way	9522	93	0.6	0.5	0.5			
46	Right-of-way	10254	81	0.5					
47	Residential	7131	78	0.5					
48	Lawn	6244	77	0.6					
49	Residential	4868	71	0.5	0.5	0.5			
50	Residential	3192	66	0.5	0.5	0.5			
51	Residential	1973	42	0.7	0.5	0.5			
52	Lawn	3058	294	0.5					
53	Lawn	4527	286	0.5	0.6	0.5			
54	Right-of-way	6224	281	0.5					
55	Residential	7933	278	0.5	0.5	0.5			
56	Residential	9818	288	0.5					
58	Residential	5305	300	0.5					

Station	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
59	Residential	4487	319	0.7					
60	Residential	3571	338	0.5					
61	Residential	3576	11	0.5					
62	Residential	5602	55	0.5	0.7	0.5			
63	Cemetery	5292	50	0.7	0.8	0.6			
64	Lawn	6361	57	0.5					
65	Residential	7040	63	0.5					
66	Residential	8295	65	0.5					
67	Residential	9516	68	0.5					
68	Residential	11265	73	0.8					
69	Residential	11911	63	0.5					
70	Residential	10747	52	0.5					
71	Residential	7587	44	0.5					
72	Residential	5894	21	0.9	0.6	0.5			
73	Lawn	4939	345	0.5					
74	Residential	6872	330	0.5					
75	Residential	7579	321	0.5					
76	Residential	8640	305	0.5					
77	Residential	10824	296	0.5					
78	Right-of-way	11373	308	0.5					
79	Right-of-way	10218	315	0.5					
80	Residential	8825	325	0.5					
81	Residential	7795	344	0.5					
82	Residential	7603	10	0.5					
83	Residential	8085	21	0.7					
84	Lawn	8736	31	**2.8**	**5.3**	0.6			
85	Residential	9911	40	0.5					
86	Residential	11331	47	0.5	0.5	0.5			
87	Residential	13009	55	0.6					
88	Right-of-way	13274	45	0.5					
89	Residential	11406	35	0.5	0.5	0.5			
90	Residential	9879	21	0.8					
91	Residential	9385	11	0.5					
150	Residential	1745	21	0.8					
151	Woodlot	2351	19	0.6					
157	Residential	1749	21	0.9	0.7	0.5	0.6	0.5	0.6
158	Tilled	1775	23	0.8	0.6	1.0	0.8	1.1	0.5
159	Lawn	7665	29	0.5					
160	Untilled	7695	29	0.7	0.5	0.5	0.5	0.5	0.5
161	Tilled	7594	30	0.5	0.5	0.5	0.5	0.5	0.5
162	Right-of-way	4601	26	0.5	0.5	0.5	0.5	0.5	0.5
163	Tilled	4604	26	0.5	0.5	0.5	0.9	0.5	0.5
164	Residential	11360	36	0.5	0.5	0.6	0.5	0.5	0.5
165	Tilled	11356	36	0.5	0.5	0.5	0.5	0.5	0.5

Values reported represent average of duplicate samples, μg/g air-dry weight. Single samples only at Site 157 (See text)
Values shown in bold exceed Table F Guideline for molybdenum in non-agricultural soils (2.5 μg/g Mo), Shaded cells exceed Table A Guideline for molybdenum in fine-textured residential/parkland soil (40 μg/g Mo)
*Distance (meters) and direction (degrees) from INCO stack

Appendix A-15 Concentrations of strontium in soil collected in the Port Colborne area, 1998

Station	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm
1	Residential	372	318	75				
2	Boulevard	463	301	175				
3	Residential	442	275	43	43	44		
4	Residential	675	342	59	62	63		
5	Boulevard	852	332	85				
6	Residential	1083	329	33				
7	Boulevard	882	6	55				
8	Residential	1130	5	230				
9	Residential	908	16	41				
10	Boulevard	1387	32	61				
11	School yard	2072	51	41	39	41		
12	Right-of-way	3996	30	105	115	135		
14	Residential	1030	113	29	35	46		
15	Right-of-way	2134	83	36				
16	Residential	2930	87	72				
17	Right-of-way	245	243	16	24	30		
19	Right-of-way	6557	33	17	18	15		
20	Lawn	4593	91	49				
23	Right-of-way	5457	3	51				
24	Boulevard	304	323	68				
25	Boulevard	1043	338	67				
26	Boulevard	926	299	81				
27	Boulevard	1279	306	100				
28	Right-of-way	364	185	39				
29	Boulevard	1278	337	90				
30	Lawn	3602	289	36				
31	Right-of-way	2450	8	70				
32	Park	2654	357	30				
33	Park	1991	341	34	39	39		
34	Boulevard	1215	293	87				
35	Park	3308	287	18				
36	Park	1755	314	27				
37	Park	1253	275	22	16	18		
38	Boulevard	2013	288	53				
39	Residential	9547	276	27	23	23		
40	Lawn	9438	262	72				
41	Right-of-way	6114	264	31				
42	Residential	4465	268	32				
43	Right-of-way	2244	107	35	36	38		
44	Residential	6206	89	46				
45	Right-of-way	9522	93	27	24	23		
46	Right-of-way	10254	81	175				
47	Residential	7131	78	115				
48	Lawn	6244	77	45				
49	Residential	4868	71	101	101	100		
50	Residential	3192	66	25	24	23		
51	Residential	1973	42	46	35	36		
52	Lawn	3058	294	18				
53	Lawn	4527	286	40	34	34		
54	Right-of-way	6224	281	31				
55	Residential	7933	278	74	71	61		
56	Residential	9818	288	66				

Station	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm
58	Residential	5305	300	**72**				
59	Residential	4487	319	36				
60	Residential	3571	338	39				
61	Residential	3576	11	44				
62	Residential	5602	55	**65**	**65**	**66**		
63	Cemetery	5292	50	23	17	18		
64	Lawn	6361	57	**300**				
65	Residential	7040	63	38				
66	Residential	8295	65	57				
67	Residential	9516	68	35				
68	Residential	11265	73	38				
69	Residential	11911	63	**75**				
70	Residential	10747	52	52				
71	Residential	7587	44	35				
72	Residential	5894	21	**120**	**115**	**120**		
73	Lawn	4939	345	**105**				
74	Residential	6872	330	**100**				
75	Residential	7579	321	49				
76	Residential	8640	305	47				
77	Residential	10824	296	42				
78	Right-of-way	11373	308	62				
79	Right-of-way	10218	315	**88**				
80	Residential	8825	325	42				
81	Residential	7795	344	36				
82	Residential	7603	10	51				
83	Residential	8085	21	**81**				
84	Lawn	8736	31	**67**	61	**68**		
85	Residential	9911	40	32				
86	Residential	11331	47	64	**65**	60		
87	Residential	13009	55	47				
88	Right-of-way	13274	45	26				
89	Residential	11406	35	49	51	47		
90	Residential	9879	21	48				
91	Residential	9385	11	34				
150	Residential	1745	21	38				
151	Woodlot	2351	19	44				
157	Residential	1749	21	23	21	17	16	15
158	Tilled	1775	23	23	22	21	21	22
159	Lawn	7665	29	37				
160	Untilled	7695	29	**76**	**66**	54	46	41
161	Tilled	7594	30	59	49	45	28	26
162	Right-of-way	4601	26	31	27	23	19	16
163	Tilled	4604	26	32	33	32	34	32
164	Residential	11360	36	40	38	34	32	29
165	Tilled	11356	36	23	22	23	25	33

Values reported represent average of duplicate samples, μg/g air-dry weight. Single samples only at Site 157 (See text)
Values shown in bold and shaded exceed OTR_{98} Guideline for strontium in rural parkland soils (64 μg/g Sr), OTR_{98} Guideline is used because no clean-up guidelines have been developed for strontium.
*Distance (meters) and direction (degrees) from INCO stack

Appendix A-16 Concentrations of vanadium in soil collected in the Port Colborne area, 1998

Station	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
1	Residential	372	318	33					
2	Boulevard	463	301	29					
3	Residential	442	275	20	21	19			
4	Residential	675	342	43	49	42			
5	Boulevard	852	332	37					
6	Residential	1083	329	30					
7	Boulevard	882	6	26					
8	Residential	1130	5	32					
9	Residential	908	16	32					
10	Boulevard	1387	32	22					
11	School yard	2072	51	50	55	55			
12	Right-of-way	3996	30	45	55	54			
14	Residential	1030	113	31	28	23			
15	Right-of-way	2134	83	31					
16	Residential	2930	87	40					
17	Right-of-way	245	243	26	28	27			
19	Right-of-way	6557	33	39	42	38			
20	Lawn	4593	91	42					
23	Right-of-way	5457	3	49					
24	Boulevard	304	323	29					
25	Boulevard	1043	338	30					
26	Boulevard	926	299	32					
27	Boulevard	1279	306	20					
28	Right-of-way	364	185	20					
29	Boulevard	1278	337	29					
30	Lawn	3602	289	37					
31	Right-of-way	2450	8	32					
32	Park	2654	357	42					
33	Park	1991	341	47	46	45			
34	Boulevard	1215	293	37					
35	Park	3308	287	42					
36	Park	1755	314	38					
37	Park	1253	275	21	19	16			
38	Boulevard	2013	288	25					
39	Residential	9547	276	27	30	31			
40	Lawn	9438	262	34					
41	Right-of-way	6114	264	31					
42	Residential	4465	268	31					
43	Right-of-way	2244	107	40	38	36			
44	Residential	6206	89	26					
45	Right-of-way	9522	93	37	40	41			
46	Right-of-way	10254	81	37					
47	Residential	7131	78	26					
48	Lawn	6244	77	42					
49	Residential	4868	71	35	39	39			
50	Residential	3192	66	36	37	38			
51	Residential	1973	42	38	41	47			
52	Lawn	3058	294	33					
53	Lawn	4527	286	36	36	38			
54	Right-of-way	6224	281	41					
55	Residential	7933	278	35	33	39			
56	Residential	9818	288	32					
58	Residential	5305	300	38					

Station	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
59	Residential	4487	319	37					
60	Residential	3571	338	35					
61	Residential	3576	11	40					
62	Residential	5602	55	36	37	35			
63	Cemetery	5292	50	33	35	37			
64	Lawn	6361	57	37					
65	Residential	7040	63	30					
66	Residential	8295	65	29					
67	Residential	9516	68	44					
68	Residential	11265	73	39					
69	Residential	11911	63	46					
70	Residential	10747	52	48					
71	Residential	7587	44	29					
72	Residential	5894	21	41	43	43			
73	Lawn	4939	345	47					
74	Residential	6872	330	34					
75	Residential	7579	321	47					
76	Residential	8640	305	30					
77	Residential	10824	296	29					
78	Right-of-way	11373	308	34					
79	Right-of-way	10218	315	37					
80	Residential	8825	325	33					
81	Residential	7795	344	36					
82	Residential	7603	10	40					
83	Residential	8085	21	37					
84	Lawn	8736	31	42	47	38			
85	Residential	9911	40	42					
86	Residential	11331	47	47	49	48			
87	Residential	13009	55	45					
88	Right-of-way	13274	45	32					
89	Residential	11406	35	32	35	34			
90	Residential	9879	21	44					
91	Residential	9385	11	40					
150	Residential	1745	21	37					
151	Woodlot	2351	19	41					
157	Residential	1749	21	35	45	41	40	32	33
158	Tilled	1775	23	50	49	47	49	55	56
159	Lawn	7665	29	32					
160	Untilled	7695	29	39	44	46	55	57	60
161	Tilled	7594	30	44	43	49	49	55	63
162	Right-of-way	4601	26	30	30	32	14	35	37
163	Tilled	4604	26	33	35	32	34	46	49
164	Residential	11360	36	33	38	44	50	55	58
165	Tilled	11356	36	44	43	43	44	53	56

Values reported represent average of duplicate samples, μg/g air-dry weight. Single samples only at Site 157 (See text)
Values shown in bold exceed Table F Guideline for beryllium in non-agricultural soils (1.2 μg/g Be), Shaded cells exceed Table A Guideline for beryllium in fine-textured residential/parkland soil (1.2 μg/g Be)
*Distance (meters) and direction (degrees) from INCO stack

Appendix A-17 Concentrations of zinc in soil collected in the Port Colborne area, 1998

Station	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
1	Residential	372	318	***315***					
2	Boulevard	463	301	***250***					
3	Residential	442	275	***215***	***215***	***230***			
4	Residential	675	342	***230***	***260***	***325***			
5	Boulevard	852	332	145					
6	Residential	1083	329	99					
7	Boulevard	882	6	90					
8	Residential	1130	5	130					
9	Residential	908	16	145					
10	Boulevard	1387	32	35					
11	School yard	2072	51	89	110	110			
12	Right-of-way	3996	30	84	76	72			
14	Residential	1030	113	65	42	19			
15	Right-of-way	2134	83	150					
16	Residential	2930	87	92					
17	Right-of-way	245	243	64	70	41			
19	Right-of-way	6557	33	106	102	100			
20	Lawn	4593	91	87					
23	Right-of-way	5457	3	87					
24	Boulevard	304	323	***255***					
25	Boulevard	1043	338	130					
26	Boulevard	926	299	115					
27	Boulevard	1279	306	72					
28	Right-of-way	364	185	160					
29	Boulevard	1278	337	***175***					
30	Lawn	3602	289	95					
31	Right-of-way	2450	8	101					
32	Park	2654	357	100					
33	Park	1991	341	90	105	125			
34	Boulevard	1215	293	135					
35	Park	3308	287	135					
36	Park	1755	314	125					
37	Park	1253	275	160	86	51			
38	Boulevard	2013	288	115					
39	Residential	9547	276	99	105	100			
40	Lawn	9438	262	78					
41	Right-of-way	6114	264	105					
42	Residential	4465	268	45					
43	Right-of-way	2244	107	72	56	22			
44	Residential	6206	89	65					
45	Right-of-way	9522	93	115	115	115			
46	Right-of-way	10254	81	98					
47	Residential	7131	78	98					
48	Lawn	6244	77	82					
49	Residential	4868	71	110	125	115			
50	Residential	3192	66	110	115	110			
51	Residential	1973	42	150	91	82			
52	Lawn	3058	294	92					
53	Lawn	4527	286	63	69	61			
54	Right-of-way	6224	281	92					
55	Residential	7933	278	125	110	72			
56	Residential	9818	288	66					
58	Residential	5305	300	87					

Station	Land Use	Distance*	Direction*	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
59	Residential	4487	319	155					
60	Residential	3571	338	66					
61	Residential	3576	11	82					
62	Residential	5602	55	***165***	***175***	***170***			
63	Cemetery	5292	50	130	130	120			
64	Lawn	6361	57	100					
65	Residential	7040	63	84					
66	Residential	8295	65	61					
67	Residential	9516	68	104					
68	Residential	11265	73	90					
69	Residential	11911	63	96					
70	Residential	10747	52	115					
71	Residential	7587	44	53					
72	Residential	5894	21	104	97	97			
73	Lawn	4939	345	140					
74	Residential	6872	330	***225***					
75	Residential	7579	321	150					
76	Residential	8640	305	59					
77	Residential	10824	296	98					
78	Right-of-way	11373	308	73					
79	Right-of-way	10218	315	94					
80	Residential	8825	325	63					
81	Residential	7795	344	63					
82	Residential	7603	10	78					
83	Residential	8085	21	***215***					
84	Lawn	8736	31	105	94	76			
85	Residential	9911	40	92					
86	Residential	11331	47	185	170	145			
87	Residential	13009	55	115					
88	Right-of-way	13274	45	99					
89	Residential	11406	35	115	120	115			
90	Residential	9879	21	115					
91	Residential	9385	11	105					
150	Residential	1745	21	***235***					
151	Woodlot	2351	19	120					
157	Residential	1749	21	140	140	110	130	70	48
158	Tilled	1775	23	100	100	110	115	107	69
159	Lawn	7665	29	160					
160	Untilled	7695	29	275	14	14	130	109	98
161	Tilled	7594	30	135	110	104	77	73	80
162	Right-of-way	4601	26	91	92	91	97	76	73
163	Tilled	4604	26	79	83	78	78	87	91
164	Residential	11360	36	295	310	240	135	86	84
165	Tilled	11356	36	90	89	89	86	88	89

Values reported represent average of duplicate samples, μg/g air-dry weight. Single samples only at Site 157 (See text)
Values shown in bold exceed Table F Guideline for zinc in non-agricultural soils (160 μg/g Zn), Shaded cells exceed Table A Guideline for zinc in fine-textured residential/parkland soil (800 μg/g Zn)
*Distance (meters) and direction (degrees) from INCO stack

Appendix B
Derivation and Significance of the MOE "Ontario Typical Range" Soil Guidelines.

The MOE "Ontario Typical Range" (OTR) guidelines are being developed to assist in interpreting analytical data and evaluating source-related impacts on the terrestrial environment. The OTRs are used to determine if the level of a chemical parameter in soil, plants, moss bags, or snow is significantly greater than the normal background range. An exceedence of the OTR_{98} (*the OTR_{98} is the actual guideline number*) may indicate the presence of a potential point source of contamination.

The OTR_{98} represents the expected range of concentrations of chemical parameters in surface soil, plants, moss bags, and snow from areas in Ontario not subjected to the influence of known point sources of pollution. The OTR_{98} represents 97.5 percent of the data in the OTR distribution. This is equivalent to the mean plus two standard deviations, which is similar to the previous MOE "Upper Limit of Normal" (ULN) guidelines. In other words, 98 out of every 100 background samples should be lower than the OTR_{98}.

The OTR_{98} may vary between land use categories even in the absence of a point source of pollution because of natural variation and the amount and type of human activity, both past and present. Therefore, OTRs are being developed for several land use categories. The three main land use categories are Rural, New Urban, and Old Urban. Urban is defined as an area that has municipal water and sewage services. Old Urban is any area that has been developed as an urban area for more than 40 years. Rural is all other areas. These major land use categories are further broken into three subcategories; Parkland (which includes greenbelts and woodlands), Residential, and Industrial (which includes heavy industry, commercial properties such as malls, and transportation rights-of-way). Rural also includes an Agricultural category.

The OTR guidelines apply only to samples collected using standard MOE sampling, sample preparation, and analytical protocols. Because the background data were collected in Ontario, the OTRs represent Ontario environmental conditions.

The OTRs are not the only means by which results are interpreted. Data interpretation should involve reviewing results from control samples, examining all the survey data for evidence of a pattern of contamination relative to the suspected source, and where available, comparison with effects-based guidelines. The OTRs are particularly useful where there is uncertainty regarding local background concentrations and/or insufficient samples were collected to determine a contamination gradient. OTRs are also used to determine where in the anticipated range a result falls. This can identify a potential concern even when a result falls within the guideline. For example, if all of the results from a survey are close to the OTR_{98} this could indicate that the local environment has been contaminated above the *anticipated average,* and therefore the pollution source should be more closely monitored.

The OTRs identify a range of chemical parameters resulting from natural variation and normal human activity. ***As a result, it must be stressed that values falling within a specific OTR_{98} should not be considered as acceptable or desirable levels; nor does the OTR_{98} imply toxicity to plants, animals or humans.*** Rather, the OTR_{98} is a level which, if exceeded, prompts further investigation on a case by case basis to determine the significance, if any, of the above normal concentration. Incidental, isolated or spurious exceedences of an OTR_{98} do not necessarily indicate a need for regulatory or abatement activity. However, repeated and/or extensive exceedences of an OTR_{98} that appears to be related to a potential pollution source does indicate the need for a thorough evaluation of the regulatory or abatement program.

The OTR_{98} supersedes the Phytotoxicology ULN guideline. The OTR program is on-going. The number of OTRs will be continuously updated as sampling is completed for the various land use categories and sample types. For more information on these guidelines please refer to *Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags, and Snow. MOE Report Number HCB-151-3512-93, PIBs Number 2792, ISBN 0-778-1979-1.*

Appendix C
Derivation and Significance of the MOE Soil Clean-up Guidelines

The MOE soil clean-up *Guidelines* have been developed to provide guidance for cleaning up contaminated soil. The *Guidelines* are not legislated Regulations. Also, the *Guidelines* are not action levels, in that an exceedence does not automatically mean that a clean-up must be conducted. The *Guidelines* were prepared to help industrial property owners decide how to clean-up contaminated soil when property is sold and/or the land-use changes. Most municipalities insist that contaminated soil is cleaned up according to the MOE *Guidelines* before they will approve a zoning change for redevelopment, therefore, even though the *Guideline* is voluntary most industrial property owners and developers are obliged to use it. For example, the owner of an industrial property who plans to sell the land to a developer who intends to build residential housing can use the *Guideline* to clean up the soil to meet the residential land-use criteria. In this way previously-contaminated industrial land can be re-used for residential housing without concern for adverse environmental effects.

The *Guideline* contains a series of Tables (A through F), each having criteria for soil texture, soil depth, and ground water use for various land-use categories (eg, agricultural, residential, industrial). Table F *criteria* reflect the upper range of background concentrations for soil in Ontario. An exceedence of Table F indicates the likely presence of a contaminant source. Tables A through E *criteria* are effects-based and are set to protect against the potential for adverse effects to human health, ecological health, and the natural environment, whichever is the most sensitive. By protecting the most sensitive parameter the rest of the environment is protected by default. The *Guideline criteria* take into consideration the potential for adverse effects through direct contact, and through contaminant transfer from soil to indoor air, from ground water or surface water through release of volatile gases, from leaching of contaminants in soil to ground water, or from ground water discharge to surface water. However, the *Guideline criteria may not* ensure that corrosive, explosive, or unstable soil conditions will be eliminated.

If the decision is made that remedial action is needed, the *criteria* in Tables A to F of the *Guideline* can be used as clean-up targets. In some cases, because of economic or practical reasons, it may not be possible to clean up a site using the generic *criteria* in Tables A to F. The *Guideline* provides a process, called a *site specific risk assessment*, which is used to evaluate the soil contamination with respect to conditions that are unique to the contaminated site. In a *site specific risk assessment* the proponent examines all the potential pathways through which the contamination may impact the environment and must demonstrate that because of conditions unique to that site the environment and human health will not be adversely effected if contamination above the generic *criteria* in Table A to E is left in place.

When contamination is present and a change in land-use is not planned, for example residential properties and public green spaces near a pollution source, the *Guideline* may be used in making decisions about the need for remediation. This is different from the previously described situation where a company that caused contamination on their own property decides to clean up the soil, usually at the insistence of the municipality who will not approve a zoning change unless remediation is conducted. Decisions on the need to undertake remedial action when the *Guideline criteria* are exceeded ***and*** where the land-use is not changing are made on a site by site basis using *site specific risk assessment* principals and are usually contingent on the contaminants having caused an adverse environmental effect or there is a demonstrated likelihood that the contamination may cause an adverse effect. Because of the long history of industrial operation and our practice of living close to our work place the soil in many communities in Ontario is contaminated above the effects-based *criteria* in the MOE *Guidelines*. In practice, remediation of contaminated soil on privately-owned residential property and public green spaces has only been conducted in communities when the potential for adverse health effects has been demonstrated.

The soil clean-up *Guidelines* were developed from published U.S. EPA and Ontario environmental data bases. Currently there are criteria for about 25 inorganic elements and about 90 organic compounds. Criteria were developed only if there were sufficient, defendable, effects-based data on the potential to cause an adverse effect. All of the criteria address human health and aquatic toxicity, but terrestrial ecological toxicity information was not available for all elements or compounds. The development of these clean-up *Guidelines* is a continuous program, and criteria for more elements and compounds will be developed as additional environmental data become available. Similarly, new information could result in future modifications to the existing *Guidelines*.

For more information on the MOE's soil clean-up *Guidelines* please refer to the *Guideline for Use at Contaminated Sites in Ontario. Revised February 1997*, Ontario Ministry of Environment and Energy, PIBs 3161E01, ISBN 0-7778-6114-3.

APPENDIX D
Methodology for Producing Surfer Soil Contamination Maps

Software Used

Two software packages were used to generate the maps. The data analysis and creation of the concentration contours was done using Surfer Version 6.03 for Windows 95 by Golden Software Inc. The output from Surfer was imported into ArcView GIS Version 3.1 by Environmental Systems Research Institute, Inc., and combined with base maps , roads, and bodies of water, and the final maps produced. The base map data was CanMap Street Files for Ontario Version 2, by Desktop Mapping Technologies Inc.

Data Used

All sampling stations at which 0 - 5 cm samples were collected using soil corers from undisturbed lawn areas were used in generating the contours. Results from tilled areas, and from soil pits were not used. Two locations, stations 10, 27, that met the above criteria were excluded from the analysis as the results were significantly lower than the surrounding stations. The lawns at these two sites had most likely had the surface soil replaced at some time in the recent past.

Mapping Process

The process involved in creating the maps was to analysis the data and create the desired contours using Surfer. The individual contours were exported from Surfer as AutoCad DXF files. The polygon portion of the DXF files were imported into ArcView GIS and converted into ArcView shape files. Lake Erie and the Welland canal were subtracted from each of the contour polygons where they overlapped. The resultant polygons were combined with the street and hydrographic base maps, and the station locations were imported from the Phytotoxicology Information Management System (PIMS). Layouts where then created with Legend, Labels, Scale, and Compass and printed for the report.

Areas for the Table A and Table F contour polygons were calculated using a built in ArcView procedure.

A. Surfer

For all data sets the gridding method used was Krigging and the search option was to use all data. For all contouring smoothing was set at high. All coordinates were in latitude and longitude. Only the 0 - 5 cm soil results were analyzed. The small number of 5 -10 , and 10 -15 cm stations and their geographic distribution did not lend themselves to Surfer analysis.

1. Nickel Data (0 - 5 cm Results)

a. Grid Line Geometry

	Minimum	Maximum	Spacing	# of Lines
X Direction	-79.37	-79.05	0.00214765°	150
Y Direction	42.82	42.98	0.00216216°	75

b. Nickel Contours: 43, 100, 200, 500, 1000, 2000 , 3000,4000
43, 200 (Table A & F)

2. Copper Data (0 - 5 cm Results)

a. Grid Line Geometry

	Minimum	Maximum	Spacing	# of Lines
X Direction	-79.3587	-79.1075	0.00168591°	150
Y Direction	42.86	42.9624	0.00167869°	62

b. Copper Contours: 85, 100, 150, ... , 300
85, 300 (Table A & F)

3. Cobalt Data (0 - 5 cm Results)

a. Grid Line Geometry

	Minimum	Maximum	Spacing	# of Lines
X Direction	-79.3587	-79.1075	0.00168591°	150
Y Direction	42.86	42.9624	0.00167869°	62

b. Cobalt Contours: 21, 50, 100
21, 50 (Table A & F)

B. ArcView

13. Base Map

A base map was created using CanMap Ontario Streetfile themes Hamilton-Niagra Roads, Ontario Major Roads, Ontario Highways, Hydrography, and Hamilton-Niagra Wetlands. To this was added all of the stations sampled in 1998 by importing the station coordinates and related information from the PIMS database. This base map was used as the underlying map for all other maps.

14. Import & Convert

Each of the DXF export files from Surfer were added to the base map view as DXF themes and then converted to ArcView shape files. The DXF themes were then deleted.

15. Subtract Hydrographic Layer

The DXF export did not support polygons with holes in them but sent over the main polygon with the holes represented as separate smaller polygons. This meant that when the DXF themes were converted to shape themes the holes had to be created by subtracting the smaller polygons from the larger polygons. If the resultant polygon overlapped with Lake Erie or the Welland Canal these were subtracted from the polygon in a multi-step process. Small lakes, ponds and marsh areas were not subtracted from the contour polygon.

16. Calculate Area

The area of all the polygons that made up the Table A and Table F polygons for copper, cobalt, and nickel were calculated using the ArcView script *View.CalculateAcreage*. The areas calculated were only for the coloured in the legend (ie. The Table F area is the area that exceeded the Table F guideline but is lower than the Table A guideline).

17. Final Maps

A separate ArcView Layout was produced for each of the maps consisting of the base map, stations, contour polygons, scale, compass, title, legend, and symbol for the INCO stack. Stations were only labeled at locations of interest with respect to the contour polygons. These layouts were used to print the final maps.

Appendix E

List of MOE Phytotoxicology reports of investigations conducted in the vicinity of INCO, Port Colborne (excluding investigations on private property conducted at the owner's request).

Ontario Ministry of the Environment, Phytotoxicology Section. *Vegetation Surveillance Northeast of International Nickel Co. Refinery, Port Colborne, July 1972.*

Ontario Ministry of the Environment, Phytotoxicology Section. *Phytotoxicology Surveys Conducted in the Vicinity of the International Nickel Company, Port Colborne, Ontario, 1969 - 1974.*

Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. *Phytotoxicology Surveys in the Vicinity of International Nickel Co., Port Colborne - 1975.*

Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. *Phytotoxicology Surveys in the Vicinity of International Nickel Co., Port Colborne - 1976.*

Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. *Phytotoxicology Surveys in the Vicinity of International Nickel Co., Port Colborne - 1977.*

Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. *Nickel and Other Metals in Vegetation in the Vicinity of International Nickel Company (INCO), Port Colborne - 1978.*

Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. *Phytotoxicology Surveys in the Vicinity of the INCO Refinery, Port Colborne, 1979-1980.*

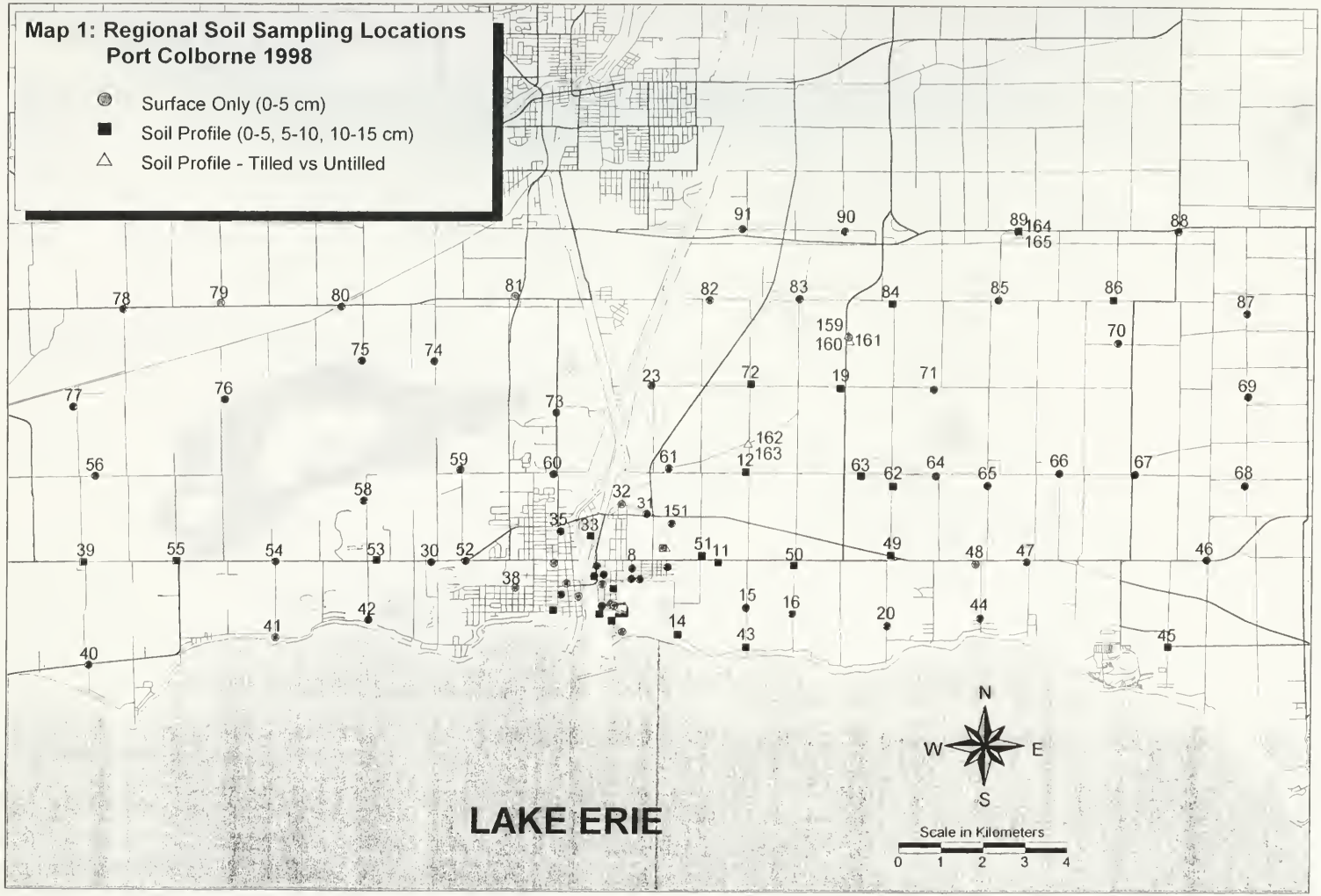
Rinne, R.J. 1983. *Contamination of Vegetation by Nickel and Other Elements in the Vicinity of INCO Limited, Port Colborne - 1981.* Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. Report Number ARB-24-83-Phyto.

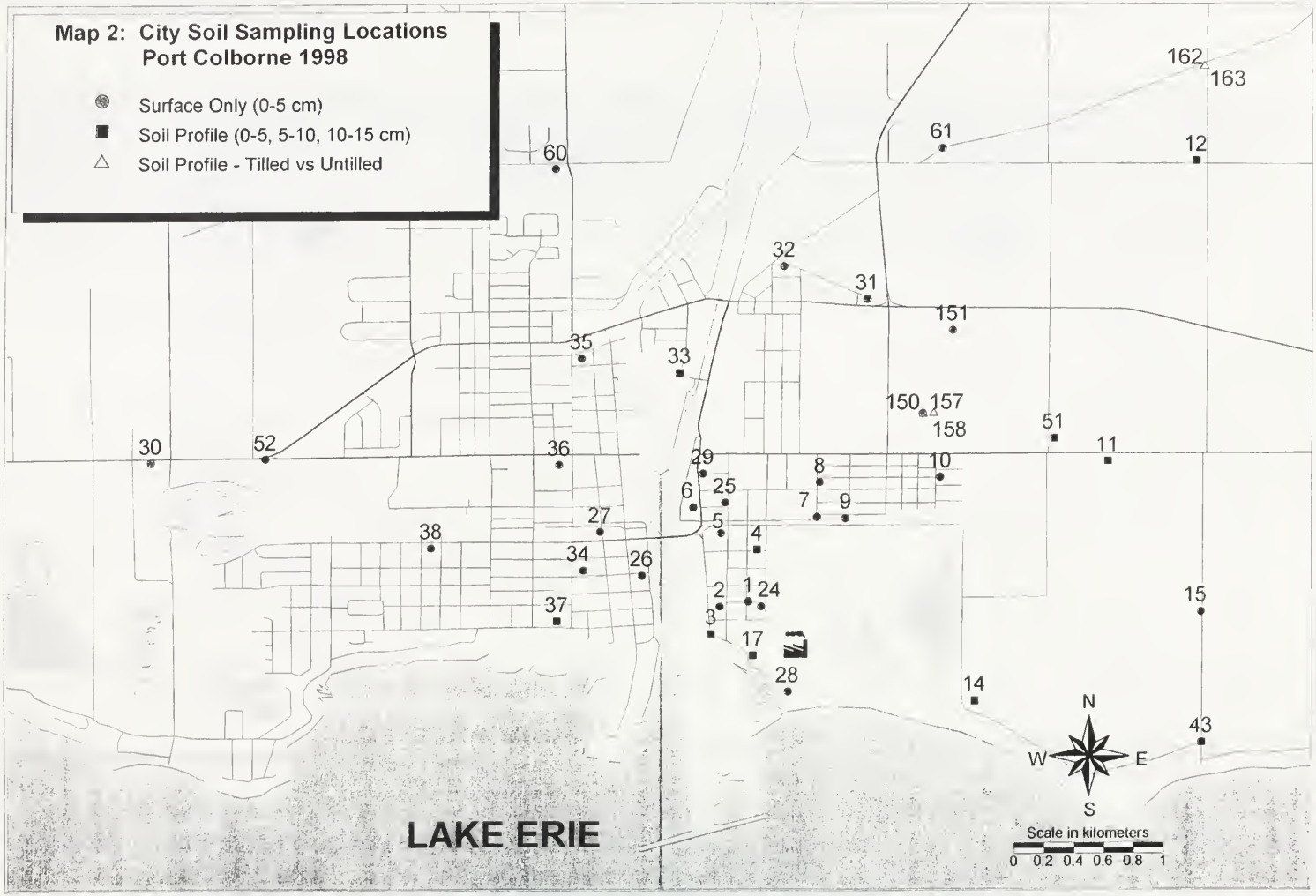
Rinne, R.J. 1983. *Contamination of Vegetation by Nickel and Other Elements in the Vicinity of INCO, Port Colborne - 1982.* Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. Report Number ARB-195-83-Phyto.

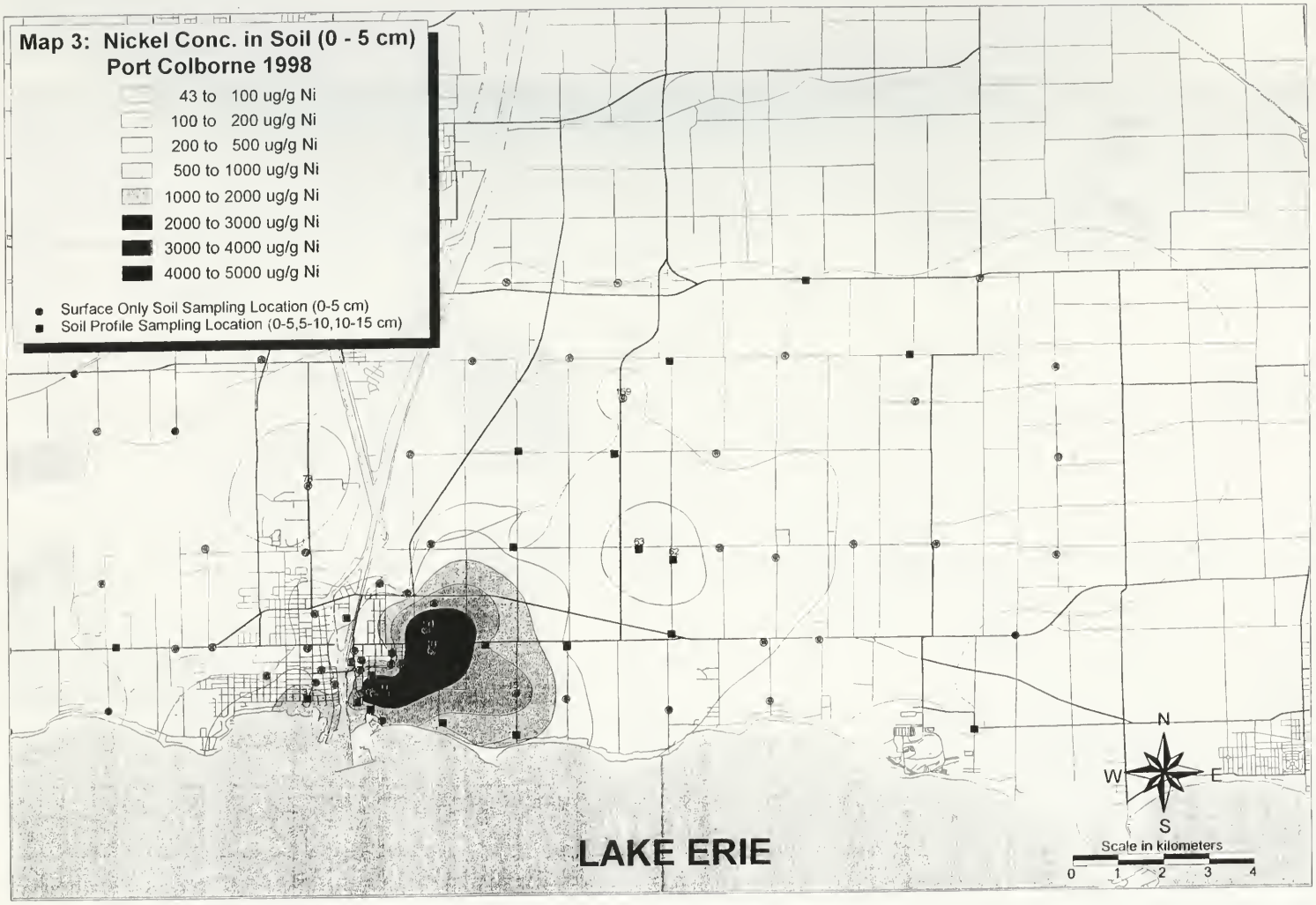
Rinne, R.J. 1985. *Contamination of Vegetation by Nickel and Other Elements in the Vicinity of INCO, Port Colborne - 1983, 1984.* Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. Report Number ARB-117-85-Phyto.

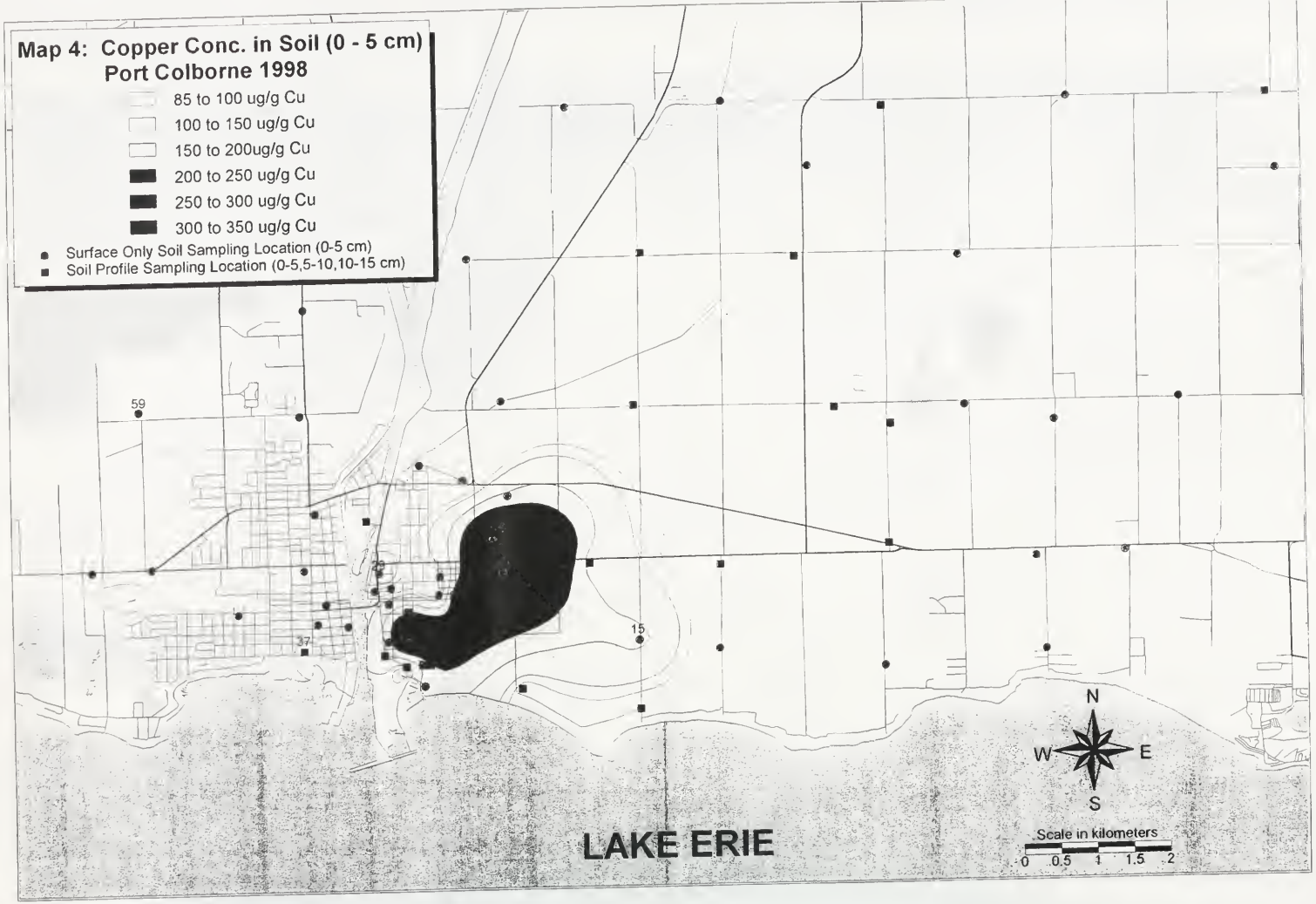
Rinne, R.J. 1989. *Phytotoxicology Assessment Surveys in the Vicinity of INCO Ltd., Port Colborne - 1985, 1986.* Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. Report Number ARB-001-88-Phyto.

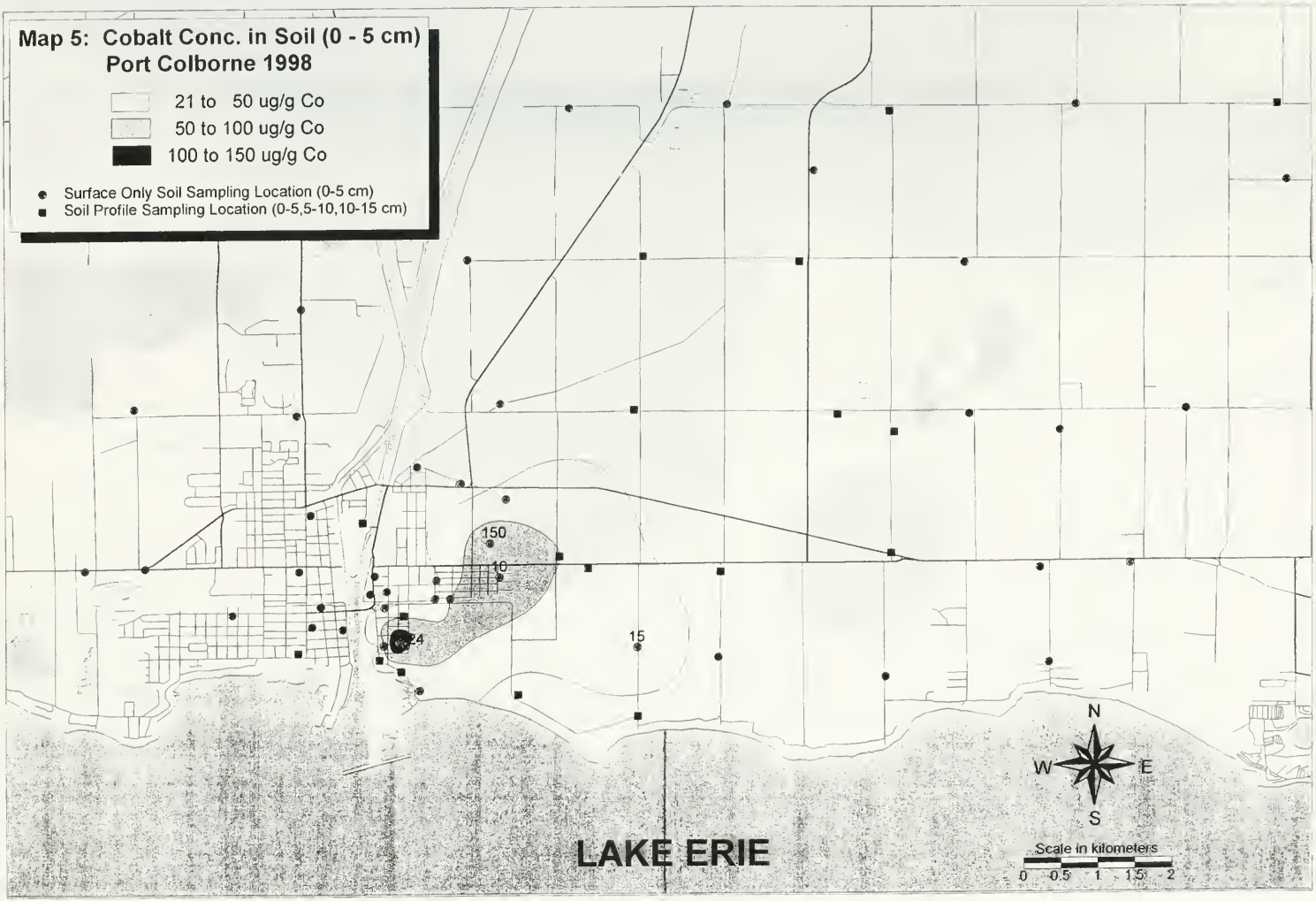
McLaughlin, D., Bisessar, S. 1994. *Phytotoxicology Survey Report: International Nickel Company Limited, Port Colborne - 1991.* Ontario Ministry of the Environment, Standards Development Branch, Phytotoxicology Section. Report Number SDB-003-3512-92.


Map 1: Regional Soil Sampling Locations
Port Colborne 1998
Surface Only (0-5 cm)
Soil Profile (0-5, 5-10, 10-15 cm)
Soil Profile - Tilled vs Untilled
LAKE ERIE
N
W
E
S
Scale in Kilometers
0 1 2 3 4

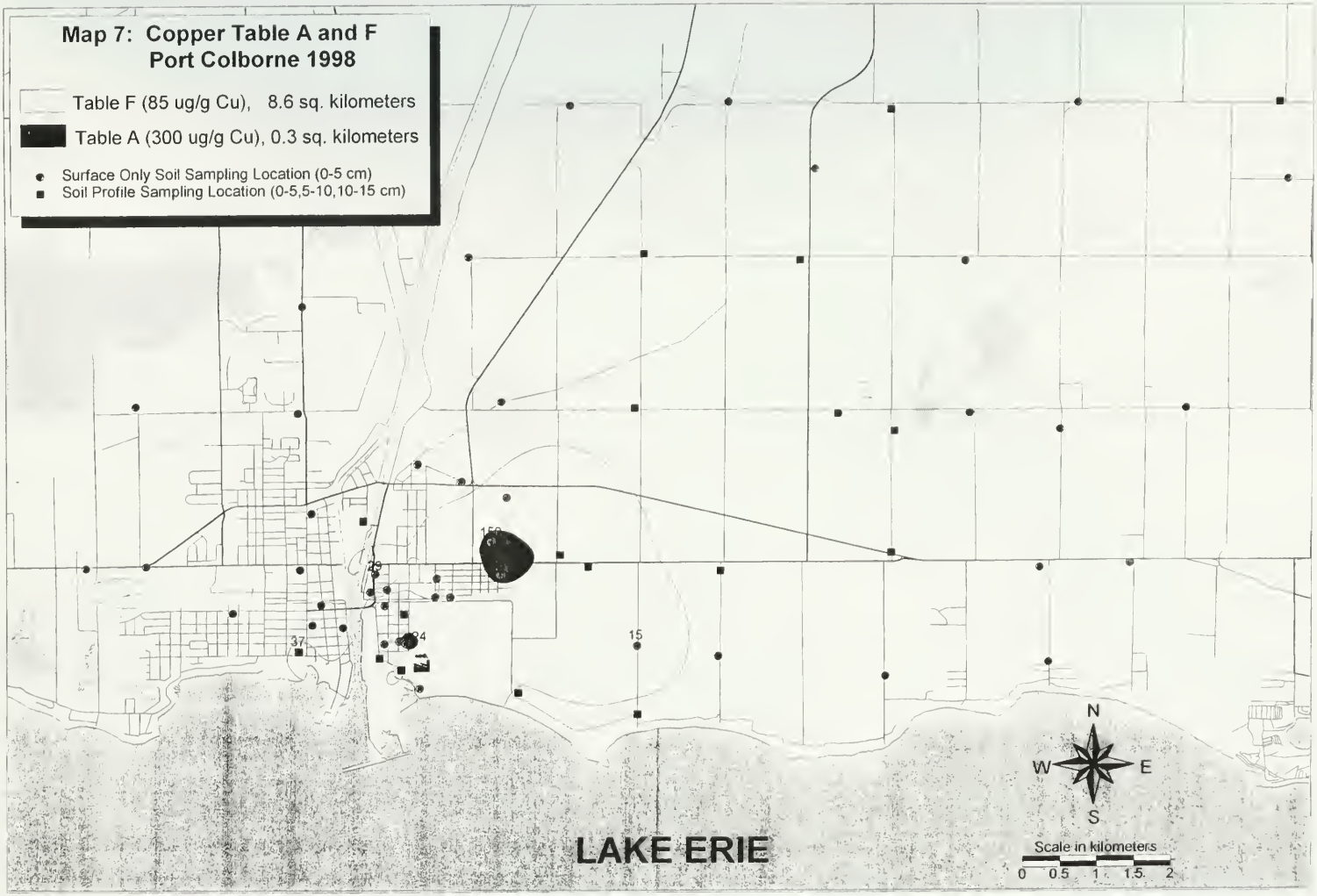

Map 2: City Soil Sampling Locations
Port Colborne 1998
Surface Only (0-5 cm)
Soil Profile (0-5, 5-10, 10-15 cm)
Soil Profile - Tilled vs Untilled
162
163
61
12
60
32
31
151
35
33
150
157
158
51
30
52
36
29
8
10
11
6
25
7
9
27
5
38
4
34
26
2
1
24
15
37
3
17
28
14
43
N
W
E
S
LAKE ERIE
Scale in kilometers
0 0.2 0.4 0.6 0.8 1

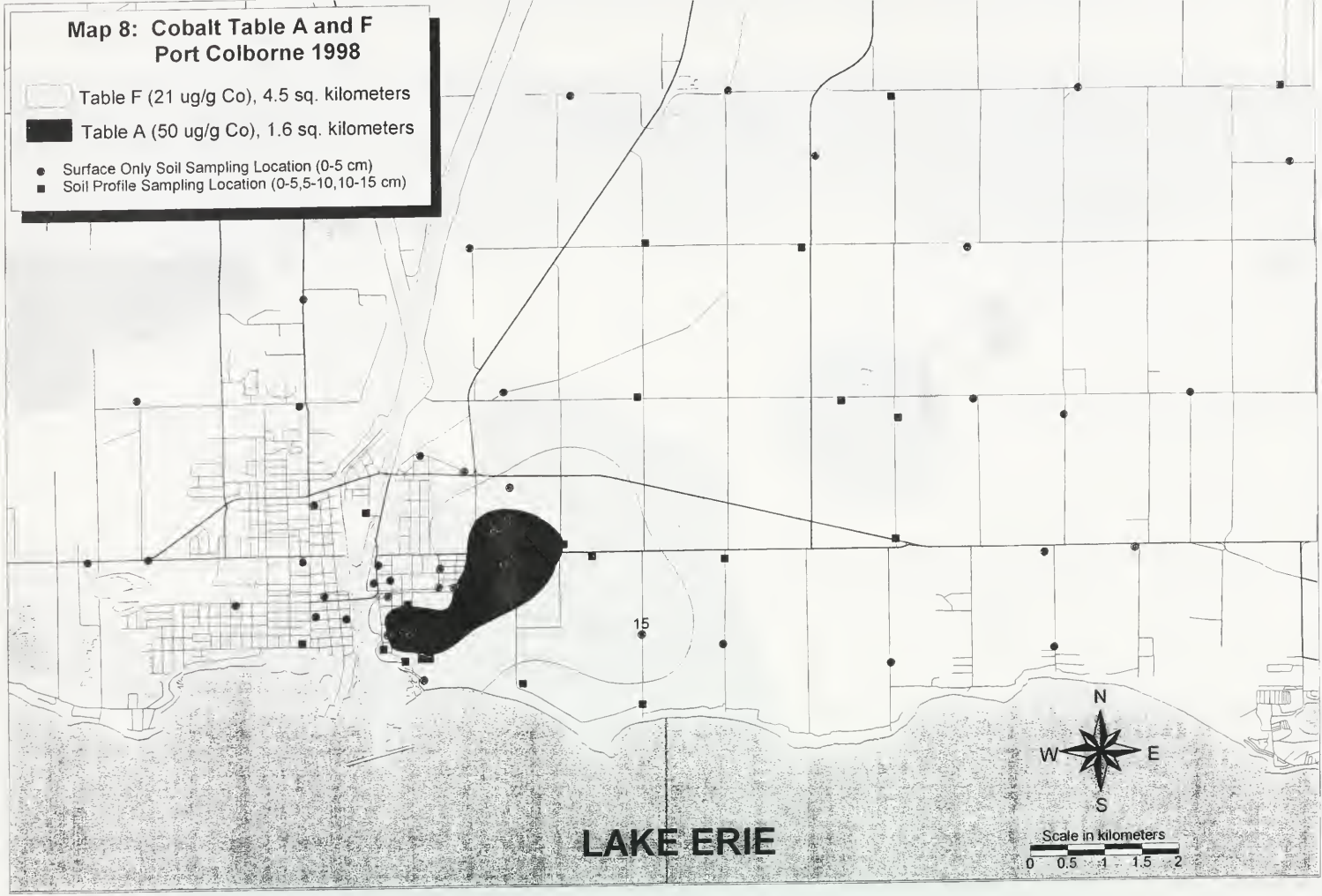

Map 3: Nickel Conc. in Soil (0 - 5 cm)
Port Colborne 1998
43 to 100 ug/g Ni
100 to 200 ug/g Ni
200 to 500 ug/g Ni
500 to 1000 ug/g Ni
1000 to 2000 ug/g Ni
2000 to 3000 ug/g Ni
3000 to 4000 ug/g Ni
4000 to 5000 ug/g Ni
Surface Only Soil Sampling Location (0-5 cm)
Soil Profile Sampling Location (0-5,5-10,10-15 cm)
LAKE ERIE
N
W
E
S
Scale in kilometers
0 1 2 3 4


Map 4: Copper Conc. in Soil (0 - 5 cm)
Port Colborne 1998
85 to 100 ug/g Cu
100 to 150 ug/g Cu
150 to 200ug/g Cu
200 to 250 ug/g Cu
250 to 300 ug/g Cu
300 to 350 ug/g Cu
Surface Only Soil Sampling Location (0-5 cm)
Soil Profile Sampling Location (0-5,5-10,10-15 cm)
59
37
15
LAKE ERIE
N
W
E
S
Scale in kilometers
0 0.5 1 1.5 2


Map 5: Cobalt Conc. in Soil (0 - 5 cm)
Port Colborne 1998
21 to 50 ug/g Co
50 to 100 ug/g Co
100 to 150 ug/g Co
Surface Only Soil Sampling Location (0-5 cm)
Soil Profile Sampling Location (0-5,5-10,10-15 cm)
150
10
24
15
LAKE ERIE
N
W
E
S
Scale in kilometers
0 0.5 1 1.5 2


Map 6: Nickel Table A and F
Port Colborne 1998
Table F (43 ug/g Ni), 140 sq. kilometers
Table A (200 ug/g Ni), 19 sq. kilometers
Surface Only Soil Sampling Location (0-5 cm)
Soil Profile Sampling Location (0-5,5-10,10-15 cm)
LAKE ERIE
N
W
E
S
Scale in kilometers
0 0.5 1 1.5 2


Map 7: Copper Table A and F
Port Colborne 1998
Table F (85 ug/g Cu), 8.6 sq. kilometers
Table A (300 ug/g Cu), 0.3 sq. kilometers
Surface Only Soil Sampling Location (0-5 cm)
Soil Profile Sampling Location (0-5,5-10,10-15 cm)
28
37
24
15
N
W
E
S
LAKE ERIE
Scale in kilometers
0 0.5 1 1.5 2


Map 8: Cobalt Table A and F
Port Colborne 1998
Table F (21 ug/g Co), 4.5 sq. kilometers
Table A (50 ug/g Co), 1.6 sq. kilometers
Surface Only Soil Sampling Location (0-5 cm)
Soil Profile Sampling Location (0-5,5-10,10-15 cm)
15
LAKE ERIE
N
W
E
S
Scale in kilometers
0 0.5 1 1.5 2